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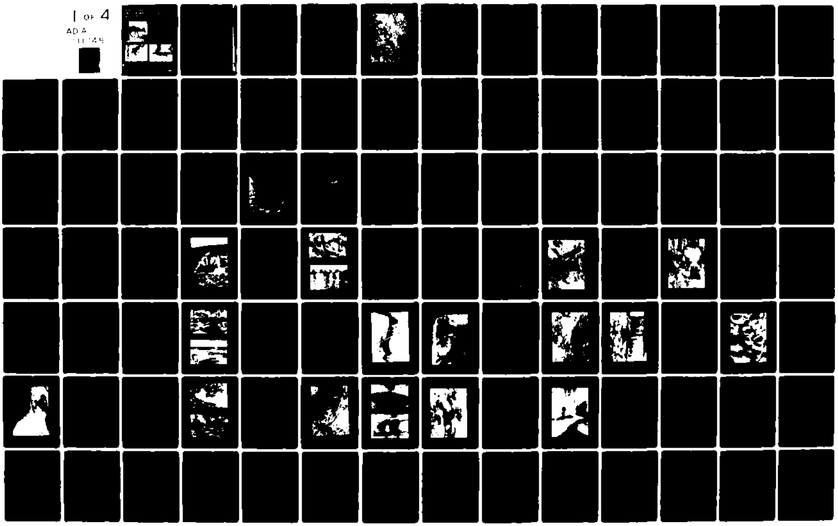

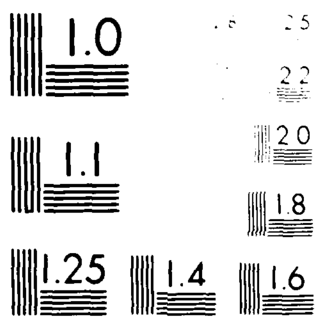
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# NORTH FORK SNOQUALMIE RIVER BASIN WILDLIFE STUDY

#28

AD A111745

**Final Report of**

**State of Washington, Department of Game,**

**Under Contract to**

**U.S. Army Corps of Engineers, Seattle District**





STEVEN J. SWEENEY - PRINCIPAL INVESTIGATOR (TERRESTRIAL STUDIES)
KEITH W. KURKO - PRINCIPAL INVESTIGATOR (AQUATIC STUDIES)
THOMAS C. JUELSON - PROJECT MANAGER

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March 1981
U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT

## Cover Photos

Upper left: The North Fork Snoqualmie River basin harbors an unusually high density of black-tailed deer.

Lower left: Pacific treefrogs inhabit the many wetlands in the basin.

Lower right: The North Fork Snoqualmie drainage contains large numbers of rainbow, cutthroat, and brook trout. These fish support a significant recreational fishery.

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In March 1981, the Washington Department of Game, under contract to the Corps of Engineers, Seattle District, completed a 2-year wildlife study of the North Fork Snoqualmie River basin in western Washington. The purpose of the study was to: 1) document wildlife in the vicinity of a proposed dam and reservoir project on the North Fork Snoqualmie River; 2) predict project impacts to wildlife; and 3) describe ways to lessen or offset these impacts.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

# North Fork Snoqualmie River Basin
# Wildlife Study


Steven J. Sweeney — Principal Investigator - Terrestrial Studies
Keith W. Kurko — Principal Investigator - Aquatic Studies
Thomas C. Juelson — Project Manager



Final Report of
Washington State Department of Game,
under contract to U.S. Army Corps of
Engineers, Seattle District

Contract DACW67-79-C-0050
23 February 1979 - 25 March 1981


The technical findings and conclusions contained in this report are those of the authors and do not necessarily reflect the views of the sponsoring agency.

Newborn black-tailed deer fawn in the North Fork Snoqualmie River basin.

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## LIST OF APPENDICES

## ACKNOWLEDGMENTS

We conducted much of this study on land belonging to the Weyerhaeuser Company. For permitting us access to their land, answering our technical questions on forestry practices and wildlife, and helping us when our truck broke down, we thank the many Weyerhaeuser employees we contacted.

Technical aides Leo Salo and William Bradbury provided skillful assistance during the first year of the study. Bradbury also supplied many of the references concerning dam-related impacts to aquatic macroinvertebrates. Dr. Donald Reynolds, University of Washington Professor of Electrical Engineering, suggested changes in our radiotelemetry equipment which proved invaluable. And Sherry Eisner deserves special credit for the many days she volunteered, monitoring radio-collared deer.

We also thank persons from the following agencies and groups for their periodic field assistance: Seattle District Corps of Engineers, U.S. Fish and Wildlife Service Olympia Office, Seattle Audubon Society, Washington Department of Game Sultan River Study, and the University of Washington College of Forest Resources Wildlife Internship Program. Technical aide William Bradbury, and artists Karen Helmerson, Bridgette McNamera, and Jaime Orogo prepared many of the report figures and illustrations.

Finally, we thank the personnel of the University of Washington Fisheries Publication Center for their diligence and care in typing this report.

# EXECUTIVE SUMMARY

In March 1981, the Washington Department of Game, under contract to the Corps of Engineers, Seattle District, completed a 2-year wildlife study of the North Fork Snoqualmie River basin in western Washington. The purpose of the study was to: 1) document wildlife in the vicinity of a proposed dam and reservoir project on the North Fork Snoqualmie River; 2) predict project impacts to wildlife; and 3) describe ways to lessen or offset these impacts.

The dam and reservoir project was proposed by a mediation team in 1974, as part of a comprehensive program to reduce flood damage in the Snohomish River basin. This program was known as the Snohomish Mediated Agreement (SMA).

Late in 1980, just before the wildlife study was completed, the Corps determined that the dam and reservoir sites proposed in the SMA were not economically justified. Extensive design features needed to control reservoir seepage would make the project cost more than the benefits it could provide. The Corps also judged the damsite to be not technically suitable, because soils underlying the dam and reservoir slopes could liquify during critical earthquakes. Accordingly, the Corps of Engineers will not recommend the project for Federal construction.

Following is a summary of the wildlife study.

1) We constructed habitat maps of the North Fork Snoqualmie River and its major tributaries based upon their physical characteristics and the percent of streambank vegetated. A 3.0 to 4.6-m (10 to 15-ft) waterfall in Black Canyon at river mile (RM) 3.1 is a major migration barrier preventing upstream movement of several fish species. Above the proposed reservoir's high pool elevation, Sunday Creek and the upper North Fork Snoqualmie River were rated "good" for reservoir trout spawning. GF, Philippa, and Lennox Creeks were considered poor. The upper North Fork Snoqualmie River contained the best juvenile trout rearing habitat.

   Eighty-two ponds were identified within the reservoir's high pool zone. In addition to these ponds the proposed reservoir would inundate approximately 8.8 miles of river and about 3.0 miles of major tributary streams. During part of the year, much of the area around the periphery of the proposed reservoir would consist of exposed mudflats.

2) Water quality in the North Fork Snoqualmie basin is presently good. Alkalinity and nutrient values are quite low in the upper river and may possibly be limiting aquatic production. The proposed North Fork Snoqualmie Reservoir would be oligotrophic, similar to other

existing western Washington reservoirs (e.g., South Fork Tolt, Chester Morse, and Spada Reservoirs).

During summer, water temperatures in the river below the proposed dam at times could be 4 to 5°C (7.2 to 9.0°F) colder than at present. During winter, the river at times could warm 3 to 4°C (5.4 to 7.2°F) above normal.

3) Only two aquatic macrophytes were observed growing in the river--fennel-leaved potamogeton and an unidentified horsetail. Twelve species of aquatic macrophytes were collected from two beaver ponds and two oxbow sloughs. The proposed reservoir would probably eliminate most of these aquatic plants except in seepage areas. Species and numbers of macrophytes may increase below the reregulating dam because of increased flow stability.

4) Numbers of benthic macroinvertebrates per square meter ranged from 272 to 1600 with mayflies making up between 47 and 83 percent. Fly larvae ranged from 2 to 25 percent. The most abundant insect found in the river was a heptageneiid mayfly of the genus <u>Cinygmula</u>. Midge larvae formed almost 65 percent of the invertebrates collected from two beaver ponds. From our samples the density of benthos was greater in ponds than in the river.

Benthic macroinvertebrate production in the drawdown zone of the proposed reservoir will be severely restricted by the absence of littoral vegetation and the periodic intervals of exposure. The reservoir's high pool will not usually be maintained long enough for complete benthic recolonization.

Temperature changes in the river below the proposed North Fork Snoqualmie dam may disrupt the normal life cycles of benthos and reduce biomass or diversity, or both.

Flow constancy below the reregulating dam powerhouse at RM 2.5 would have a beneficial effect on benthic standing crop. However, flows of only 50 cfs in the 3.4 miles of river between the reregulating dam and its powerhouse would decrease both benthic standing crop and production in that river section.

5) We estimated there were 18,524 ± 3,150 trout and 77,801 ± 13,230 sculpins in the approximately 8.8 miles of river that would be inundated. This figure did not include fish in the tributary streams. Cutthroat trout were the most abundant trout species in the river above RM 17.3. Brook trout achieved their maximum abundance of 11 to 15 percent between RM 14.6 and 18.2. Rainbow trout were the most abundant trout species below RM 16.4. In our block netting studies the greatest densities of trout were found at Wagner Campground, near Spur 10 bridge, and in the upper river above Spur 30

bridge. Trout biomass ranged from 0.28 $g/m^2$ to 2.17 $g/m^2$ with the highest biomass found at the station in the extreme upper river.

On our snorkel surveys the greatest number of fish seen was between RM 12.2 and 13.3 above Wagner bridge. The next two river sections with the greatest densities of observed fish were between RM 3.3 and 4.5 (a part of Black Canyon) and between RM 0.3 and 1.8 (below the community of Ernie's Grove). This latter section of river contains several fish species not found farther upstream including mountain whitefish, largescale suckers, longnose dace, and mottled sculpins. This is the first recorded occurrence of mottled sculpins above Snoqualmie Falls.

We electroshocked the five major tributaries of the proposed reservoir. Cutthroat trout were the most abundant salmonid species in all tributaries except Philippa Creek. In the latter, rainbow trout comprised 52 percent of the trout caught. We captured the greatest number of salmonids per hour and the largest shorthead sculpins in the extreme upper North Fork Snoqualmie River above the bridge of Forest Service road 2527.

6) We sampled 82 ponds by hook and line within the proposed reservoir site. Fifty-four (65.9%) contained trout. The trout population estimate for these ponds was 8,250 fish. The 95 percent asymmetrical confidence limits were 5,997 and 11,755 fish. As trout have not been stocked in North Fork Snoqualmie basin ponds since 1974, most present populations are self-sustaining. Ponds without self-sustaining populations are probably limited by lack of spawning habitat. In ponds from which we caught fish, 25 percent held both cutthroat and brook trout, 50 percent held only cutthroat trout, and 25 percent held only brook trout. Cutthroat trout were the most frequently captured fish in ponds. Two ponds sampled intensively with a fyke net and minnow traps were estimated to contain biomasses of 9.69 $g/m^2$ and 2.74 $g/m^2$ of surface area. Both ponds had a greater density of fish biomass than any river block net station.

7) When compared to other areas in the Pacific Northwest, growth of trout in the North Fork Snoqualmie River and its tributaries seems about average. The growth rate of beaver pond trout was faster than that of river and stream fish. This probably reflected warmer pond temperatures and greater benthic invertebrate food abundance.

8) The projected physical and biological characteristics of the proposed North Fork Snoqualmie reservoir were compared to six other reservoirs in Washington State. Five of the six reservoirs were in western Washington. The physical characteristics of the proposed North Fork Snoqualmie reservoir would be somewhat similar to those of the South Fork Tolt Reservoir. It has been estimated that the South Fork Tolt Reservoir contains between 5,000 and 10,000 trout.

However, the proposed North Fork Snoqualmie reservoir would have a considerably smaller minimum pool size, and would have a much greater annual drawdown. The latter would reduce benthic productivity in the reservoir, and could suffocate trout eggs in tributary streams as the water level rises in spring. On infrequent occasions, the reservoir would be completely emptied down to the riverbed. At most, we would anticipate a population of between 2,500 and 5,000 trout in the proposed North Fork Snoqualmie Reservoir. Studies in other western Washington reservoirs show that trout populations would be concentrated around the mouths of the principal tributary streams and may be cropped off relatively quickly by anglers. A reasonable recreational fishery could only be maintained by annual plantings of hatchery trout.

9) Temperature changes in the river below the proposed North Fork Snoqualmie dam may disrupt the normal life cycles of trout and reduce numbers and biomass. Growth rate, timing of spawning, timing of emergence, and availability of food may be affected.

However, high summer temperatures above 15.6°C (60°F) occasionally occur now in the North Fork Snoqualmie River. During such periods, the proposed dam would have a positive effect on rainbow trout in the downstream river by reducing these high temperatures.

One of the chief effects of the proposed reservoir would be to reduce winter high flows, and possibly augment late summer and fall flows. This less violent flow pattern could reduce scouring of trout eggs in the gravel and also maintain better quality fish habitat. However, drastically reduced flow (from a mean of nearly 700 cfs to 50 cfs) in the 3.4 miles of river between the reregulating dam and its powerhouse would severely decrease both fish biomass and production in that river section.

10) In 1979 an estimated 1245 angler use-days were spent on the river above the proposed damsite and some of its adjacent beaver ponds. Slightly over 3500 cutthroat, rainbow, and brook trout were caught. An estimated 1402 angler use-days were spent on the river below the proposed damsite. About 4032 rainbow trout were caught. A projected 2648 angler use-days were spent fishing on the entire river. The average angler fished the river 4.23 hours and caught 2.86 fish or 0.68 fish per hour. Angler success was highest in August with 4.67 fish per angler, and 1.04 fish per hour. Approximately 42 percent of all anglers in 1979 were fishing the North Fork area for the first time. Roughly 39 percent of the anglers said they were, or will, fish this area more often because of its proximity to the Seattle metropolitan area and the rising price of gasoline. About 34 percent anticipated no change in their fishing habits, while 23 percent said they would fish the area less.

Based on comparisons with Spada Reservoir on the Sultan River, total angler use of the proposed North Fork Snoqualmie reservoir may increase significantly compared to present use by river anglers. However, quality of angling as measured by fish per angler and fish per hour may decrease substantially.

11) To determine the instream flow requirements of fish in the North Fork Snoqualmie River, we used the incremental methodology developed by the Instream Flow Service Group of the U.S. Fish and Wildlife Service (FWS). The optimal flow for adult rainbow trout in the river downstream of the proposed main dam was 240 cfs. The optimal flow for adult rainbow trout below any dam built near Spur 10 bridge was 340 cfs. By correcting and estimating for tributary inflows, both of these discharges can be roughly extrapolated to 290 cfs at the USGS gage at RM 9.2.

12) We described, mapped, and calculated acreages of habitat types within the boundary of the proposed reservoir. Acreage figures for inundated habitat types were used, together with field studies, to estimate wildlife impacts of the proposed project, and to prepare a conceptual plan for wildlife mitigation. We also assisted FWS in a baseline Habitat Evaluation Procedure (HEP) of the project area. If the reservoir is built, HEP will be used to detenine whether wildlife mitigation is adequate.

13) The proposed reservoir would eliminate most existing wetlands (marshes, swamps, bogs, and ponds) in the North Fork Snoqualmie basin. Loss of these wetlands would drastically reduce the wildlife habitat diversity which distinguishes the area.

14) Assuming wildlife populations are at or near carrying capacity of the environment, the proposed reservoir would eliminate the number of animals whose habitats were inundated or otherwise destroyed. Wildlife losses would occur directly (e.g., through drowning), and indirectly through competition between animals displaced from the reservoir and those living around it. Animal numbers would decline until they reached levels which remaining habitats could support.

15) Through livetrapping studies, we estimated that the proposed reservoir would eliminate at least 9,100 mice and insectivores, and unknown numbers of chipmunks, squirrels, and weasels from the basin during summer. Reduction of small mammal populations would vary seasonally and annually.

16) Aerial photographs and field surveys of the project area indicated that 82 of 99 known ponds in the basin lie within the proposed reservoir boundary. A local trapper estimated 75 beavers and 10-14 river otters living within the area potentially inundated. We expect a dramatic decline in numbers of aquatic furbearers

(muskrat, beaver, mink, and river otter) in the basin, if the reservoir is built.

17) Pellet group surveys in the project area showed that the proposed reservoir would flood prime winter-spring range for black-tailed deer. Over 350 deer would perish as a result. Both resident and migratory deer would be affected, as indicated by radiotelemetric studies. Deer densities would therefore decline throughout the basin, and possibly in other drainages.

18) We estimated about 54 mountain goats living in the North Fork Snoqualmie drainage, based on conversations with reliable observers. Goat sightings within the proposed inundation zone suggest that a reservoir may interfere with their migration. Available information on other large mammals is summarized in the text.

19) Bird censuses in the project area indicated that the proposed reservoir would inundate breeding habitats of more than 3,200 non-game birds. Species suffering greatest proportional losses would be those nesting in wetlands, most of which would be eliminated. Cavity-nesters would also be severely reduced in the basin, because a disproportionate number of snags occur in and around wetlands. A few species which winter on the reservoir or feed around its margin could increase slightly. However, negative impacts of the project to non-game birds far outweigh this small benefit.

20) From spring call counts we estimated 82 adult blue grouse breeding within the proposed inundation zone. Tabulation of waterfowl sightings by habitat type indicate that a reservoir would severely reduce breeding duck populations in the basin. Observations of most band-tailed pigeons at elevations above the proposed reservoir suggest that project impacts to these birds would be minor.

21) We found active nests of two pairs of raptors--American kestrel and golden eagle--in the project area. The pair of golden eagles is one of only ten known nesting pairs of this species in western Washington. Sightings of several other species of hawks and owls during the breeding season suggest that they nest in the basin, as well. We are unsure how the reservoir would affect the pair of golden eagles nesting in the basin. Other raptors whose nest sites and hunting ranges were inundated would have to compete with their neighbors outside the reservoir. Populations would inevitably decline to levels which remaining habitats could support.

22) Our field observations of amphibians, and their known habitat preferences, indicate that the proposed reservoir would severely reduce most amphibian populations in the basin. Large fluctuations in reservoir level would provide little suitable habitat to help offset losses of vital wetlands and streams. Of reptiles occurring in

the basin, common garter snakes, which favor wetlands, would be most severely impacted by a reservoir.

23) Through a detailed field survey, we determined that more than 2,200 deer hunter use-days were spent in the North Fork Snoqualmie basin during 1979. At least 55 deer were harvested. Two-thirds of hunters interviewed were from Greater Seattle. This finding suggests that much of the basin's recreational importance lies in its proximity to a major metropolitan area. If the proposed reservoir is built, we predict fewer deer harvested and fewer hunters using the basin, than without the project.

24) The proposed reservoir would also eliminate hunting opportunities for black bear, bobcat, and grouse within the zone of inundation. Impacts on mountain goat hunting would depend upon how the reservoir affects the local goat population.

25) Information supplied by local trappers indicates that the proposed reservoir site yields a good furbearer harvest, particularly of beaver. We expect a large reduction in populations <u>and</u> harvests of aquatic furbearers, if a reservoir is built.

26) A one-day survey of recreationists at the North Fork Snoqualmie hunter check station showed that over one-third of visitors were non-hunters. This result, combined with our observations at other times of year, suggests that camping, hiking, and other recreation in the basin equals or exceeds total hunting and fishing use. The proposed reservoir would reduce some kinds of recreational opportunities, while increasing others. We urge that recreational benefits of the project be evaluated only after thorough field study.

27) The following mitigation measures could be used to help reduce and offset project impacts to wildlife. Should these methods fail to achieve specific mitigation goals, new methods would be tried until mitigation is successful.

a) Plant hatchery fish in the reservoir and some beaver ponds.
b) Supply recommended instream flows.
c) Improve reservoir tributary streams for trout rearing and spawning.
d) Minimize downstream temperature changes.
e) Obtain a public fishing access easement along the river.
f) Monitor accidental flushing of fish from the reservoir.
g) Fund studies of downstream ramp rate effects in the river.
h) Investigate enhancement of stream production by addition of nutrients.
i) Selectively clear timber and brush from the reservoir site.
j) Establish buffer strips along the river and tributary streams.
k) Create browseways to improve winter and spring deer ranges.
l) Create artificial wetlands.

m) Seed drawdown areas to provide food for wildlife.
n) Fertilize winter and spring deer ranges.
o) Retain and create snags for wildlife nesting and feeding.
p) Preserve old growth forest—a threatened habitat.
q) Build nest structures for ducks and ospreys.
r) Change forest practices to benefit wildlife.
s) Build crossings and escape ramps into the power canal for continued mammal movements.
t) Build and rehabilitate roads to minimize wildlife impacts.
u) Manage habitat in the power line corridor for wildlife.
v) Preserve or enhance other sites.
w) Fund studies to monitor impacts and mitigation.

# INTRODUCTION

## Study Purpose and Background

This is the final report of a 2-year aquatic and terrestrial wildlife study in the North Fork Snoqualmie River basin. We performed the study under contract to the Seattle District, U.S. Army Corps of Engineers. The purpose of the study was to: 1) document wildlife in the vicinity of a proposed dam and reservoir project on the North Fork Snoqualmie River; 2) predict project impacts to wildlife; and 3) describe ways to lessen or offset these impacts.

The dam and reservoir project was proposed by a mediation team in 1974, as part of a comprehensive program to reduce flood damage in the Snohomish River basin. This program was known as the Snohomish Mediated Agreement (SMA).

The Corps began feasibility level studies of the SMA in late 1978. Late in 1980 they determined that the dam and reservoir sites proposed in the SMA were not economically justified, due to extensive design features required to control reservoir seepage. The damsite was also judged to be not technically suitable, because soils underlying the dam and reservoir slopes could liquify during critical earthquakes. <u>Accordingly, the dam and reservoir proposed in the SMA and discussed throughout this report have been found unsuitable for Federal construction, and will not be recommended by the Corps of Engineers</u>.

## Environmental Setting

The North Fork Snoqualmie River drains roughly 272 $km^2$ (105 $mi^2$) of timbered, mountainous land on the west slope of the Cascade Range. It is part of the much larger Snohomish River system (Fig. 1). At its confluence with the Middle Fork, the North Fork Snoqualmie is only 43 km (27 mi) east of Seattle. Elevations in the North Fork drainage range from 125 m (410 ft) at river mouth, to 1,796 m (5,894 ft) on Lennox Mountain. The drainage contains many alpine lakes and streams, fed by runoff from melting snow.

Thousands of years ago, the North Fork Snoqualmie River may have flowed west toward Puget Sound. Deposits from the last Puget glacier(s) apparently forced the river to bend southward, uniting it with the rest of the Snoqualmie River (Manning 1978). Above its confluence, the North Fork passes through a deep, narrow gorge between river miles (RM) 2.7 and 4.3, dropping over 183 m (600 ft) in elevation. Black Canyon, as this gorge is known, is characterized by old growth forest, short, violent rapids, and numerous falls.

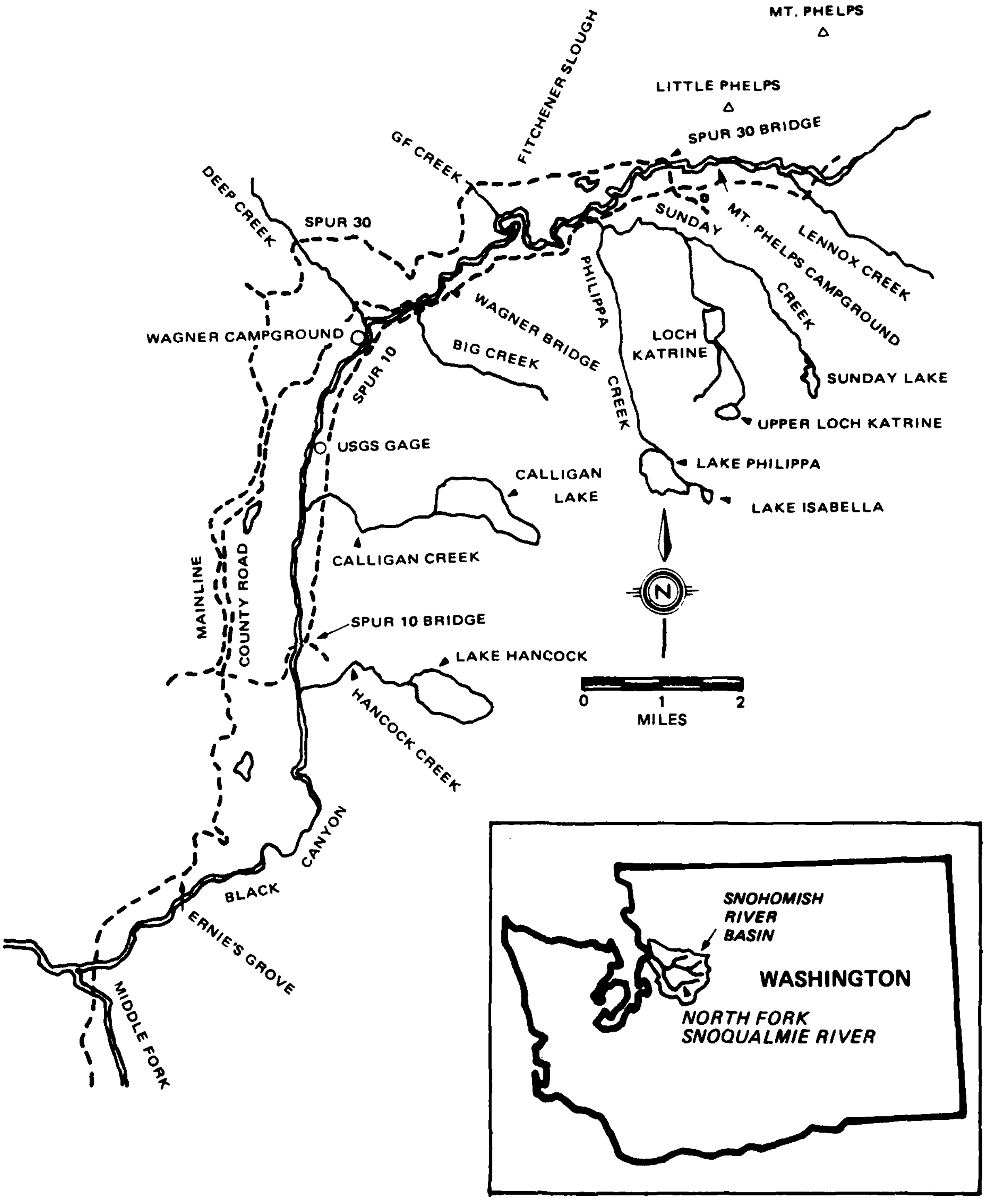



Figure 1. The North Fork Snoqualmie River Drainage

The same glacial deposits which altered the course of the lower North Fork Snoqualmie River, also dammed the upper river, creating a large lake (Manning 1978). The dam eventually broke, and the lake drained, but only after it had partly filled with sediment. Today, the old lakebed is clearly evident as a broad, flat valley bottom, with meandering streams and oxbows (Photo 1).

The climate of the North Fork Snoqualmie drainage, as elsewhere in the western Washington Cascades, is typically wet in winter and dry in summer. Average annual precipitation ranges from 152 cm (60 in) at the river mouth to 356 cm (140 in) near the headwaters at Lake Kanim (U.S. Army Corps of Engineers 1968). During winter months, snow cover is usually constant above 762 m (2,500 ft) el.

Characteristic forest tree species include Douglas fir, western hemlock, and western red cedar. Pacific silver fir is common at higher elevations, and red alder is abundant on recently disturbed sites. Herbaceous species which typically invade logged areas include fireweed, pearly everlasting, and foxglove. Shrub communities are usually dominated by salmonberry, red elderberry, and huckleberry species.

Major landowners in the North Fork Snoqualmie drainage are Weyerhaeuser Co., Washington Department of Natural Resources (WDNR), and the U.S. Forest Service (USFS). Timber production is the principal industry, with recreation secondary. The two WDNR campgrounds and one USFS campground in the drainage receive heavy recreational use during summer. So do those USFS lands in the basin within the Alpine Lakes Wilderness. Mining, once a common industry in the drainage, is apparently no longer profitable.

## Project Plan

The proposed damsite on the North Fork Snoqualmie River is about 11 air miles north and east of North Bend, Washington (Fig. 2). The site is at river mile (RM) 12.2, near Wagner bridge in Section 20, T.25N., R. 9E, WM. Figure 3 is a river mile index map obtained by combining maps produced by the Washington Department of Fisheries (Williams et al. 1975) and the Pacific Northwest River Basins Commission (1969).

The dam would have an earthfill embankment with an impervious core and a gross volume of 5,400,000 cubic yards (COE 1976). It would be 1,700 ft long and have a total height of about 211 ft from the river bed at 1,330 ft above sea level to its crest elevation at about 1,541 ft. A chute-type spillway, which could pass a 63,000 cfs flood, would be constructed on the left abutment.

The primary purpose of the dam would be flood control, but water supply and hydropower would be other possible uses. The original location of the damsite was at RM 11.7 and the reservoir's original high

Photo 1. Aerial view of the North Fork Snoqualmie River basin, looking downstream. The broad, flat valley bottom was formed when glacial deposits dammed the upper river, creating a large lake. Meandering streams and oxbows now punctuate the landscape.

Figure 2 . North Fork Snoqualmie River system with proposed reservoir, reregulating reservoir, and reregulating reservoir powerhouse.

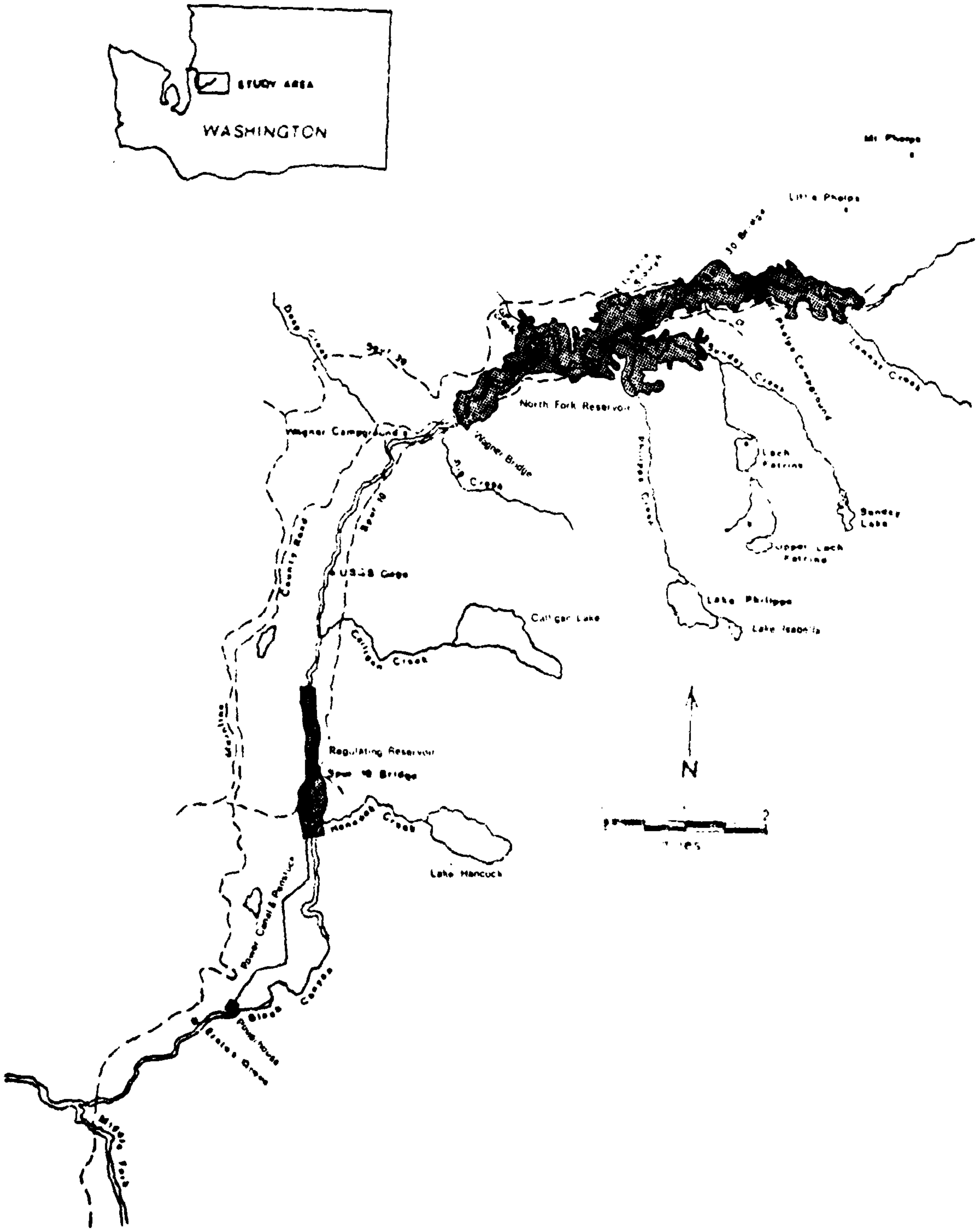
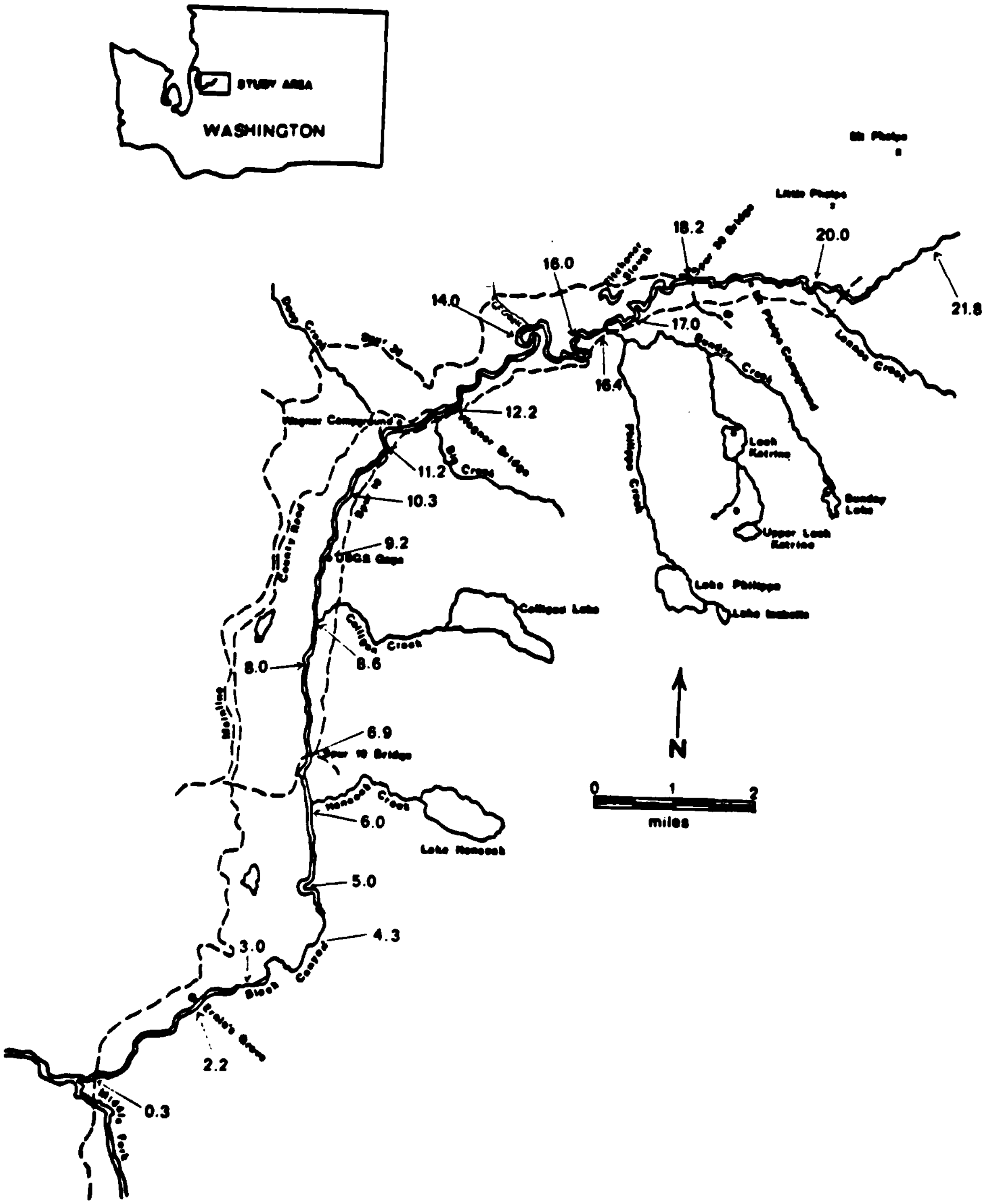


Figure 3. River mile index to North Fork Snoqualmie River.



pool elevation was 1,545 ft. In 1980 the COE relocated the damsite to RM 12.2 and lowered the reservoir's projected high pool elevation to 1,532 ft. Figure 4 shows area and capacity curves for the proposed dam at RM 11.7.

At its high pool elevation of 1,532 ft, the proposed reservoir would extend along the river from RM 12.2 to RM 21.0. Full pool length would be about 5.5 miles and maximum width about 1.1 miles. Approximately 1,660 acres of land would be inundated. In unusually dry years, the reservoir might be emptied to the river level of 1,330 ft.

Figure 5 is a curve showing a possible normal operating regime of the proposed reservoir based on a precipitation pattern which occurred in 1969. From November until February a winter flood control pool of 1,482 ft and 494 acres would be maintained. During this time, there is a 1 percent chance that a severe flood could raise the reservoir to its maximum elevation of 1,532 ft. In February the reservoir could be lowered an additional 12 ft to elevation 1,470 ft. From March until June the reservoir would be slowly raised 62 ft to maximum pool at 1,532 ft. During relatively dry years (about 3 out of 10), high pool elevation would not be reached. There is a two percent chance that the reservoir would be completely evacuated. This would occur during September and October of an unusually dry year. Elevation 1,330 ft is the level of the riverbed, but for practical purposes, elevation 1,375 ft would leave the reservoir almost emptied (with only 1 percent of the total capacity). Maximum possible drawdown from elevation 1,532 ft to 1,330 ft would be 202 ft.

Normal high pool would last from early June until mid-or-late July. The pool level would decrease to about 1,520 ft by early September and recede to the normal minimum pool of 1,482 ft by early November.

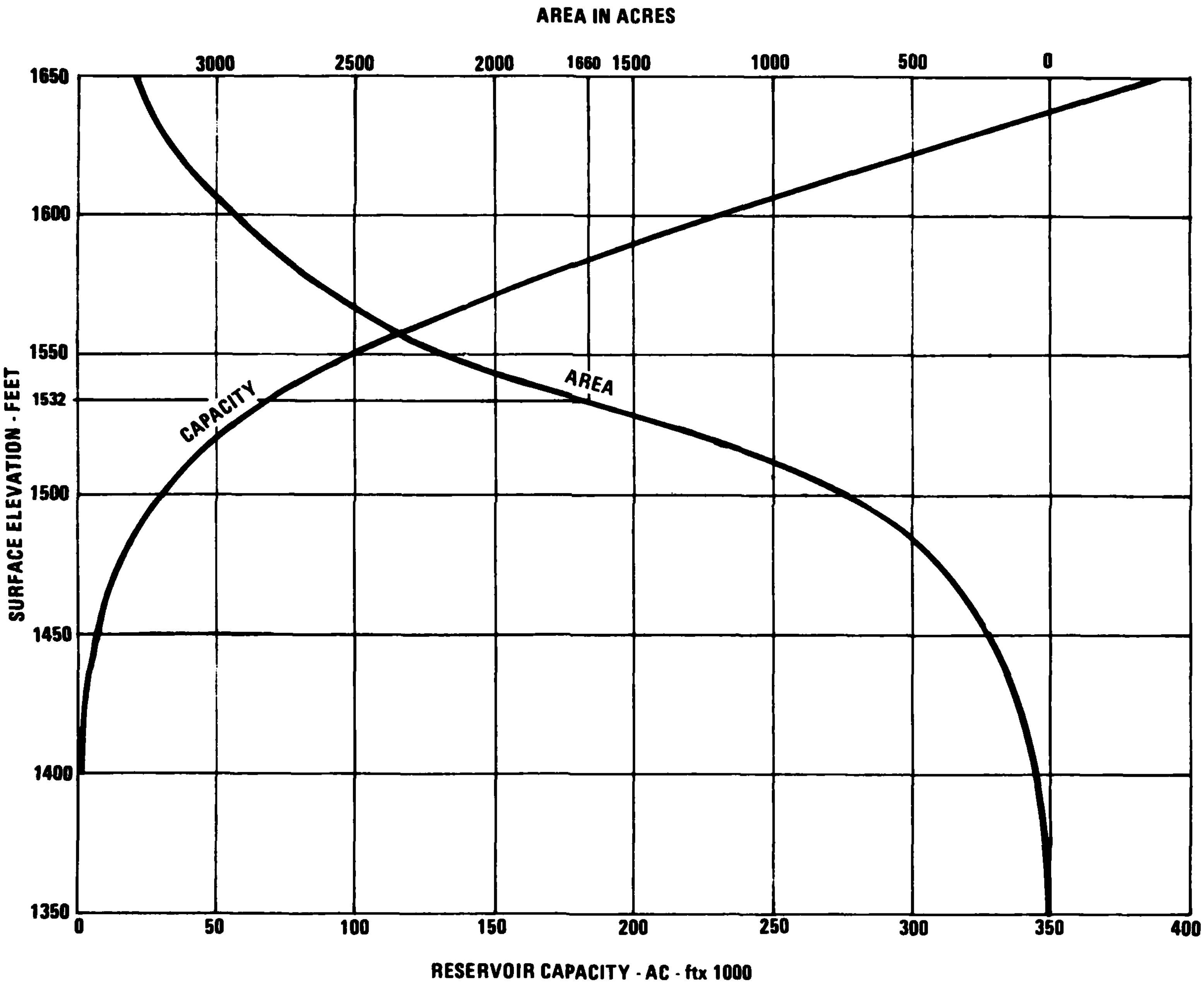
Information was not available on projected daily or monthly discharges and flow fluctuations for the river below the proposed dam.

Although not an official part of the Snohomish Mediated Agreement a reregulating dam and reservoir has also been studied by the COE. The reregulation project alternative would consist of a reregulating dam at RM 5.9 and a power canal and penstock leading to a high-head powerhouse at RM 2.5 (Fig. 2).

The dam would be a combination earthfill and concrete-gravity structure about 1,050 ft long. The earthfill embankment would have an impervious core and contain about 150,000 cubic yards of fill. Maximum height would be 80 ft from the foundation to the crest elevation of 1,081 ft.

A 16-ft-wide, 11,000-ft-long asphalt-lined power canal would divert water from the dam to the penstock. The steel penstock (pipe) would be 8.5 ft in diameter and 2,000 ft long. It would lead to a powerhouse at

Figure 4. Area and capacity curves for the proposed North Fork Snoqualmie reservoir at the R.M. 11.7 site



NORTH FORK SNOQUALMIE POOL REGULATION
Average Water Year - 1969

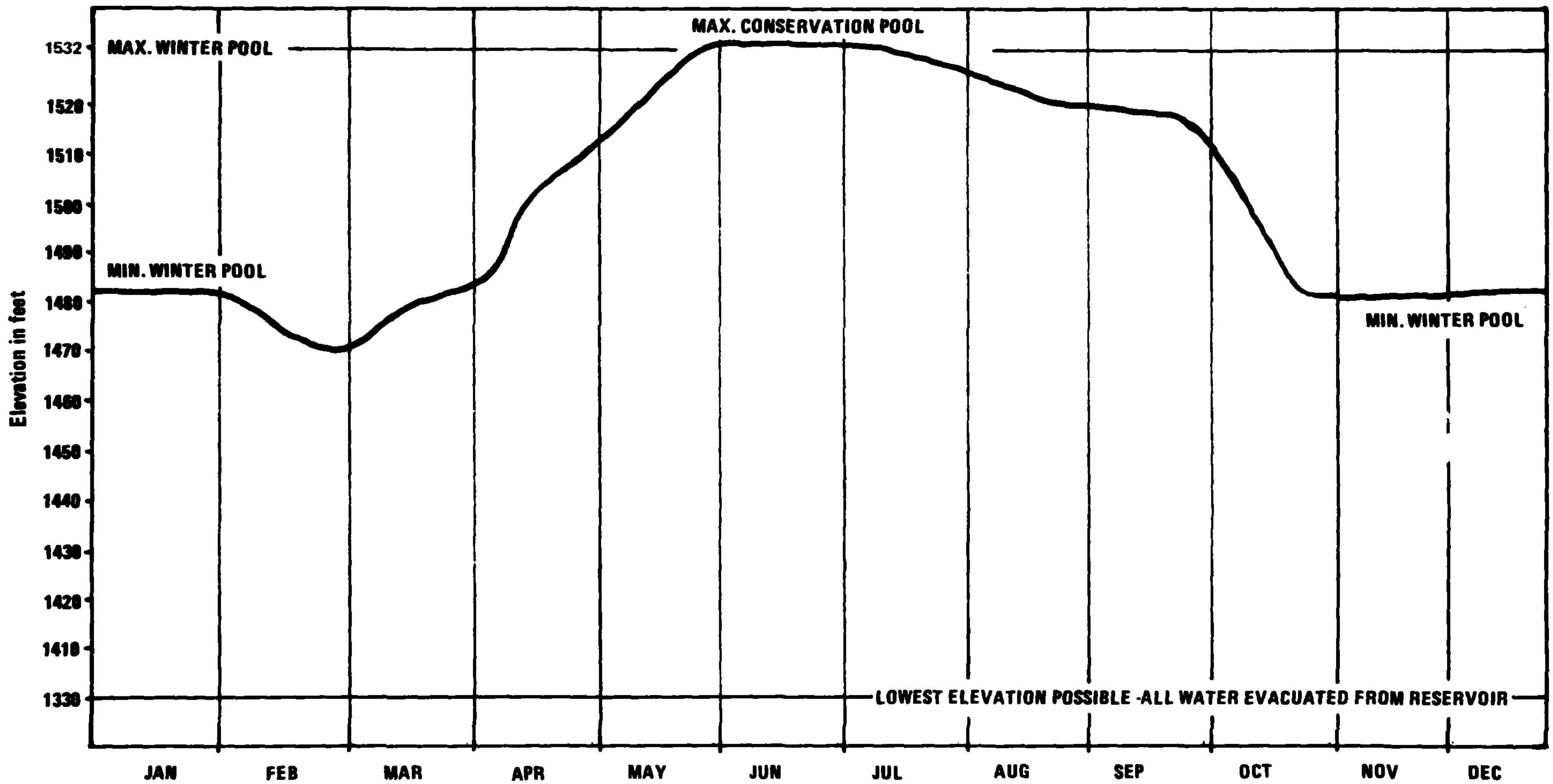



Figure 5. Pool Regulation Curve for the Proposed North Fork Snoqualmie Reservoir

RM ^.5 near the community of Ernie's Grove. The powerhouse would have a generating capacity of 30,000 kilowatts.

Water would be diverted from a section of river which includes the steep-walled Black Canyon. About 50 cfs would not be diverted and would be released into this 3.4 miles of river. Flow releases below the powerhouse at RM 2.5 would be relatively uniform.

The reregulating reservoir would have a length of about two miles and a maximum width of 1,500 ft. The pool would vary from 130 acres at the maximum elevation of 1,076 ft to a minimum of 70 acres at 1,060 ft. Reservoir levels would fluctuate daily.

## About This Report

This report contains results of two years' studies on wildlife resources of the North Fork Snoqualmie River system. The first year's investigations presented detailed results and established an ecological baseline against which future environmental changes could be compared (Kurko et al. 1980). In the second year of study, we refined and added to our first year's data and examined possible impacts from the proposed project. We also have presented a conceptual mitigation plan.

The following report emphasizes our second year's studies. However, we have attempted to integrate information from both years. Important details from the first year of study are either recounted in this report or referenced with a page number from the 1980 report.

Aquatic studies were concentrated upstream of the proposed North Fork Snoqualmie damsite between river miles 12.2 and 21.0. Terrestrial studies focused on the area above the proposed damsite and below 472 m (1,550 ft) el. This region covered the boundaries of the proposed reservoir. Investigations outside of the above areas were pursued less intensively.

At the request of the COE, we made a reconaissance of the proposed reregulating dam and reservoir site. We examined aerial photographs, flew over the area several times by helicopter, performed an instream flow study at Spur 10 bridge, snorkeled through Black Canyon and near the USGS gage at RM 9.2, spot-sampled fish with an electroshocker, conducted a one-day walk-through survey of the area, and recorded biological observations whenever we were in the vicinity.

Throughout this report, we refer repeatedly to several parts of the North Fork Snoqualmie drainage. The basin is defined as that part of the drainage above the proposed damsite (Wagner bridge). The lower river is that part of the river below the proposed damsite. A significant unnamed tributary flows into the North Fork Snoqualmie River on the

right bank near RM 14.7. We named this tributary GF (short for Giardia-Free) Creek and refer to it as such, throughout the text.

Shortly before we finished our second year of study the COE announced that the proposed main damsite at RM 12.2 was infeasible due to soil instability. We were instructed to complete our study as planned and report our results and recommendations. In addition to useful biological information obtained, our findings can serve as an ecological baseline if another agency or party were to reactivate or modify the proposed project.

A new site at RM 6.7 has been identified recently as a more geologically suitable location for the main storage dam. Just as soil stability is vastly different between RM 12.2 and RM 6.7, our brief surveys also indicate there are significant biological differences between the two sites. If serious consideration is given to construction of a dam at the new RM 6.7 location, biological studies should be conducted which are similar in detail to the present studies of the proposed dam and reservoir at RM 12.2.

Throughout the text, we generally used only the common name of most wildlife species. Exceptions were made in some cases, to improve clarity, or when a common name did not exist (e.g., for some aquatic insects). A complete list of common and scientific names is contained in Appendix A.

# AQUATIC STUDIES

## METHODS

### Habitat Type Mapping

To assess the physical characteristics of the North Fork Snoqualmie River, we completed a river habitat survey during the 1979 field season (Kurko et al. 1980, p. 8). We used it to aid in planning other biological studies. To determine suitability of the main tributary streams of the North Fork reservoir for salmonid spawning and rearing, we conducted a stream habitat survey during the 1980 field season. Initial data were taken from recent color aerial photographs whose scale was 1:12,000. The maps were later refined with foot surveys.

Sections of river and tributary streams were classified according to dominant physical characteristics and the percent of streambank vegetated, as described in our 1980 report (p. 8).

Locations of beaver pond, bog, and oxbow slough systems were also plotted.

### Water Quantity and Quality

Water quality data were obtained from the COE North Fork Snoqualmie sampling program which ran from 20 July 1979 to 20 June 1980 (U.S. Army Corps of Engineers 1980a). The four stations listed below were selected for basic field data collection (Fig. 6).

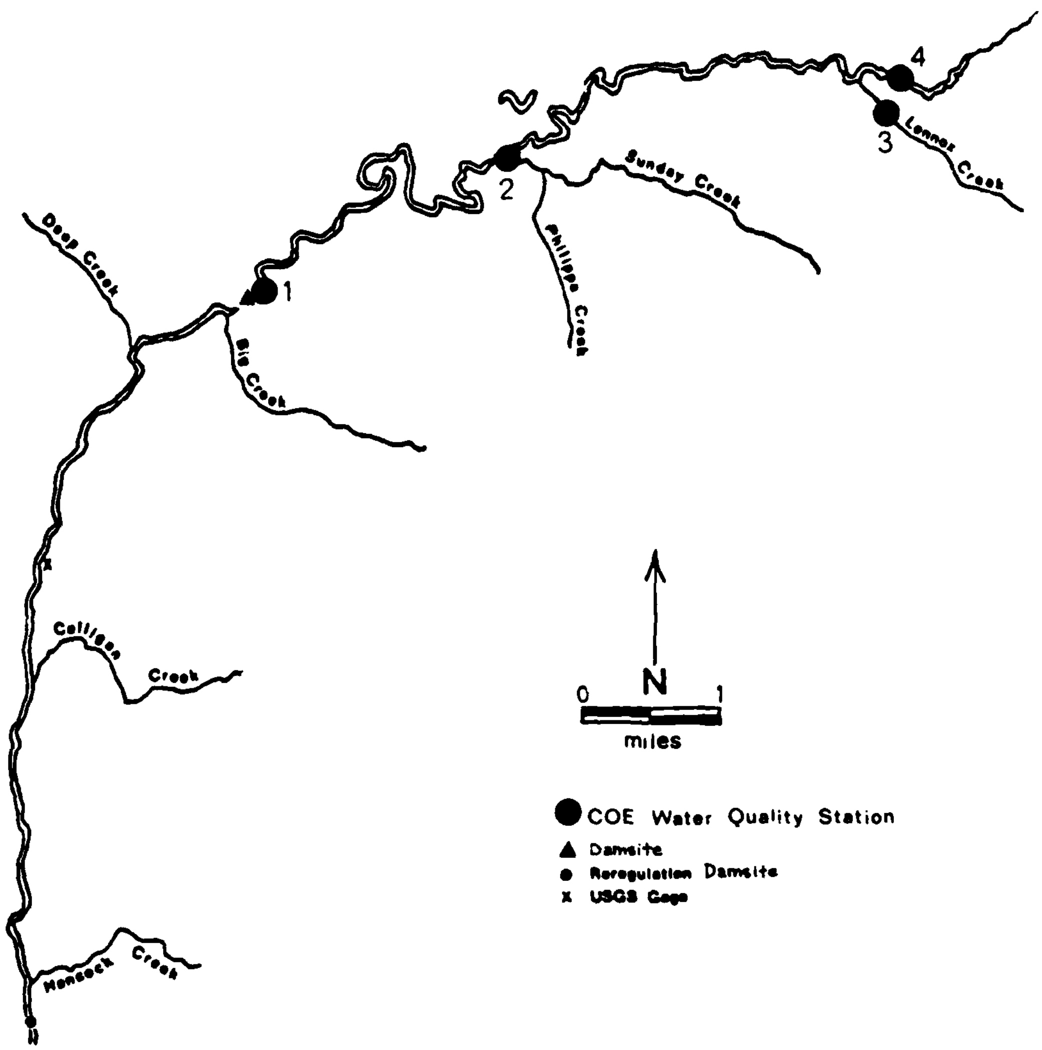
1. North Fork Snoqualmie River at Wagner bridge.
2. Sunday Creek at County Road bridge.
3. Lennox Creek at County Road bridge.
4. North Fork Snoqualmie River at Upper North Fork bridge.

Station 1 was near the proposed site of the North Fork dam. Stations 3 and 4 were near the upper end of the proposed reservoir. Station 2 was selected as a mid-reservoir sampling site.

Temperature, conductivity, pH, alkalinity, dissolved oxygen, turbidity, and phenolphthalein alkalinity were usually sampled monthly at all stations. A beaver pond was also sampled for several of these parameters one time.

For municipal and industrial water supply suitability testing, additional water quality parameters were sampled less frequently at station 1, as described in our 1980 report (p. 10).

Figure 6. Army Corps of Engineers basic water quality sampling stations in the North Fork Snoqualmie River.



The United States Geological Survey (USGS) monitored the continuous river discharge at their gaging station officially designated as "North Fork Snoqualmie River near Snoqualmie Falls, Washington, Number 12142000". This station was located at RM 9.2 (Fig. 3, p. 14).

## Aquatic Macrophytes

Aquatic macrophytes can serve as cover for juvenile and adult fish and as food for aquatic insects. They are important for their contribution to the productivity of aquatic systems.

Macrophytes were collected and identified from the North Fork Snoqualmie River, several beaver ponds, and oxbow sloughs. We described sampling methods in our 1980 report (p. 13).

## Benthos

In addition to their importance as fish food, benthic macroinvertebrate are indicators of water quality and relative productivity in freshwater environments. During the 1979 field season we collected benthic macroinvertebrates from seven river sample stations (Fig. 7) and two beaver ponds. A Mundie sampler (Mundie 1971) was used to take river samples (Fig. 8 and Photo 2), while beaver pond benthos were collected with a Ponar grab sampler. We also examined stomach samples from both river and pond trout. The detailed methods used in our benthic macroinvertebrate sampling were given in our 1980 report (pp. 13 to 16).

## Fish

### River and Streams

We estimated fish populations by block netting and electroshocking seven river sections during September 1979 (Fig. 9 and Photo 3). Blocknets eliminated movement of fish into and from the sections electroshocked. Construction and placement of blocknets (Photo 4) was described in our 1980 report (pp. 16 to 18). We measured weights and fork lengths on all fish captured. Fish larger than 130 mm (5.1 in) were tagged with a numbered, colored, plastic Floy tag just behind the dorsal fin.

Population size was estimated by the removal method of Zippen (1958). This method was described in our 1980 report (pp. 18 and 19).

From 24 July to 4 October 1979, we made 12 snorkel surveys of the North Fork Snoqualmie River (Fig. 10). We snorkeled most of the reservoir site except for the small area above the mouth of Lennox Creek.

Figure 7. Benthic macroinvertebrate sampling sites in the North Fork Snoqualmie River.

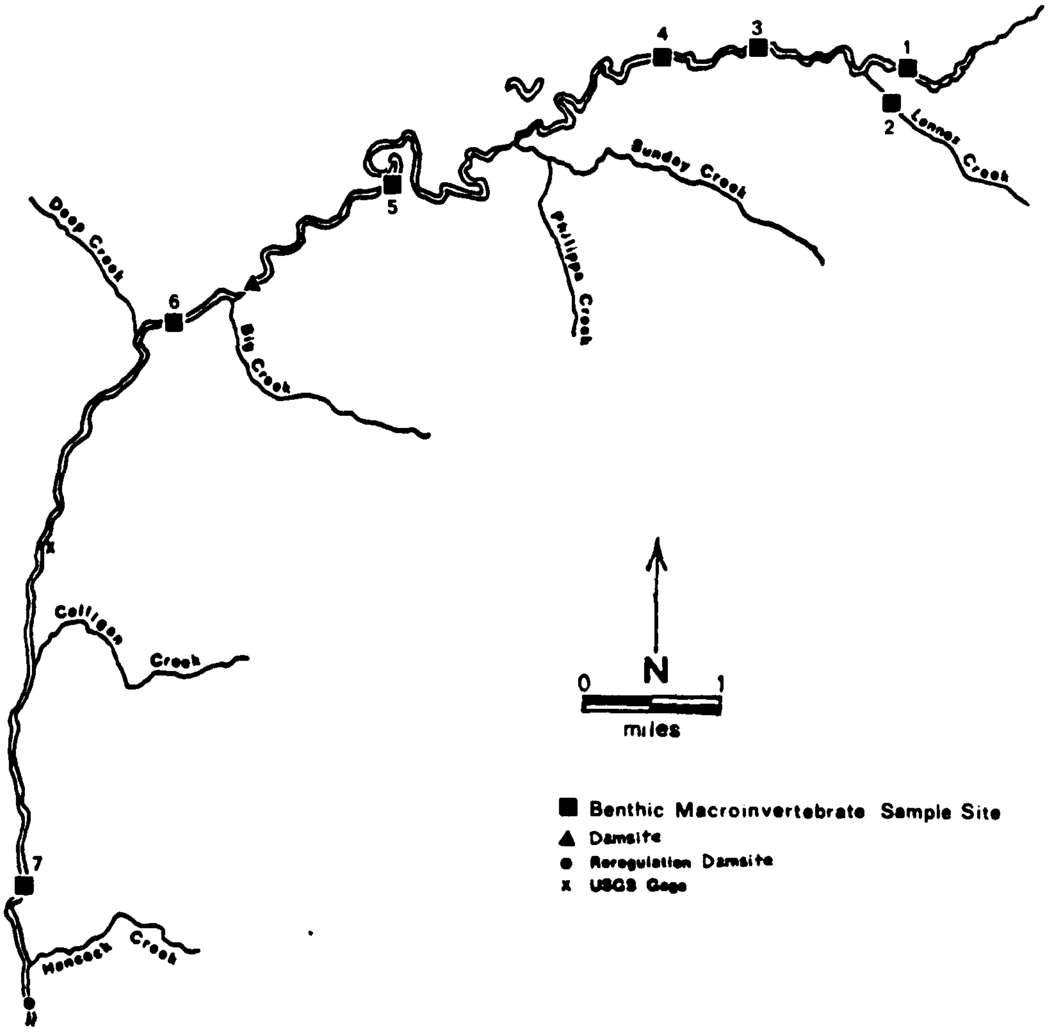


Figure 8. Mundie benthic macroinvertebrate sampler used in the North Fork Snoqualmie River.

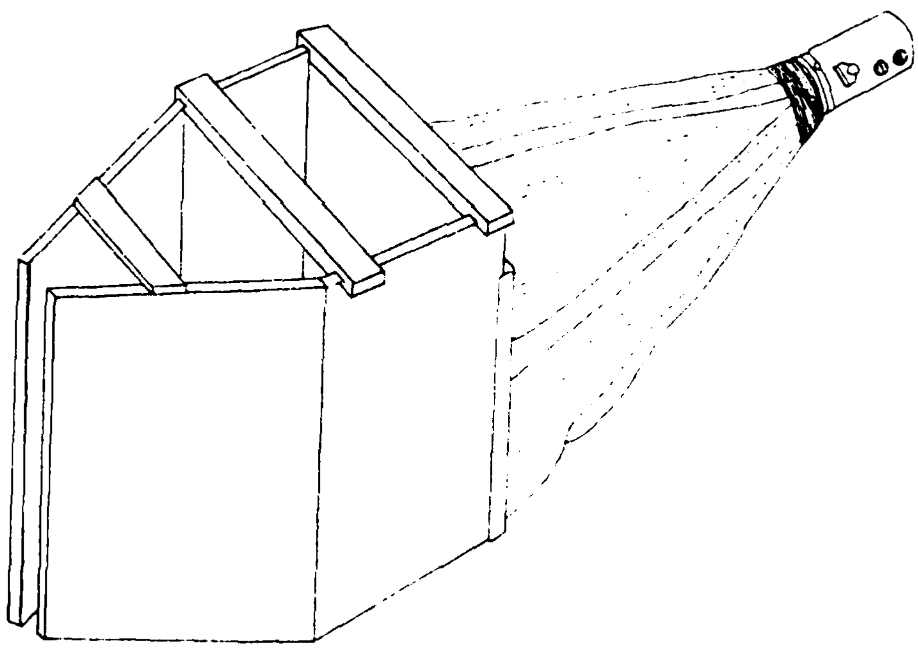


Photo 2. Collecting a benthos sample from the river with a Mundie sampler.

Figure 9. Block netting sites in the North Fork Snoqualmie River.

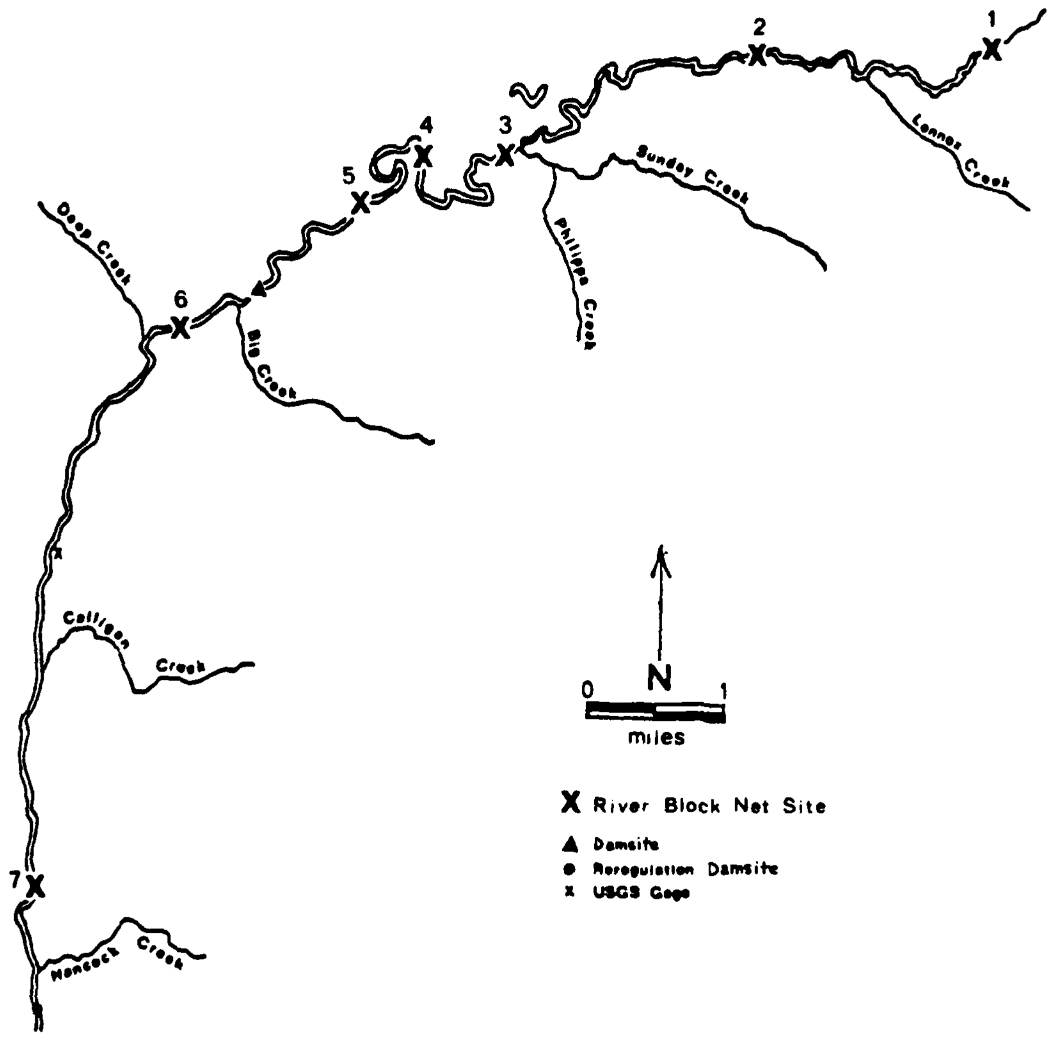
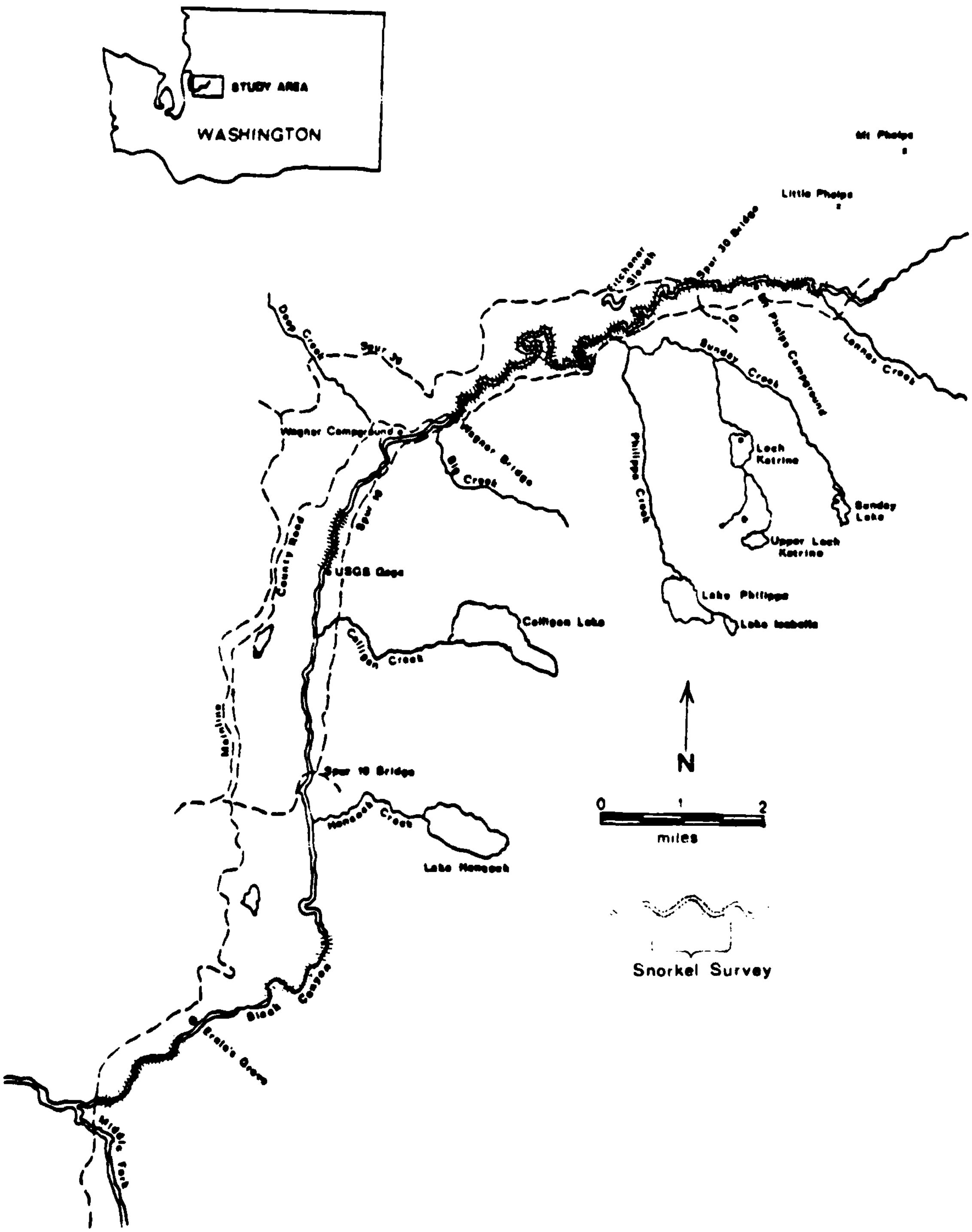


Photo 3. Electrofishing technique used in the river during block netting studies.

Photo 4. River electrofishing with block nets visible in the background.

Figure 10. Snorkel surveys in the North Fork Snoqualmie River.



Some dives were also made below the dam site in the vicinity of the proposed reregulating reservoir. Snorkel survey methods were described in our 1980 report (pp. 19 and 20).

Certain river areas were spot electroshocked during the 1979 field season. Scale samples were taken from some trout.

Washington Department of Game (WDG) and Washington Department of Fisheries (WDF) records were examined for the history of fish planting in the area.

During late September and early October 1979, we electroshocked the five major tributaries of the proposed North Fork Snoqualmie reservoir (Fig. 11). This was to investigate present use of these tributaries by resident fish. The five streams were:

1. GF Creek
2. Philippa Creek
3. Sunday Creek
4. Lennox Creek
5. Upper North Fork Snoqualmie River (above the bridge of Forest Service Road 2527)

The lengths of surveyed streams ranged from 0.6 to 1.3 miles (0.97 to 2.09 km). Three people usually operated our Coffelt model BP-1C electroshocker. This unit has an output power capability of 300 watts. We measured weights and fork lengths on all fish captured (Photo 5). Scales were taken from most trout larger than 90 mm (3.5 in).

We recorded the shocking time in each stream and converted results to numbers of fish per hour.

The proposed North Fork Snoqualmie reservoir will occasionally be drawn down to river level. Since Howard Hanson Reservoir on the Green River is drawn down to river level almost every year, comparisons between the two systems are useful. Little is known about the fish in Howard Hanson. On 17 July 1980 we set four 60-ft-long gillnets in the upper end of Howard Hanson Reservoir near the mouth of the Green River. The reservoir's pool was full. These gillnets were the "experimental type" and included five different mesh sizes in each net. The next morning we measured weights and fork lengths on all fish.

## Ponds

We numbered the systems of beaver ponds, oxbow sloughs, and bogs in the North Fork Snoqualmie basin 1 to 32 (Fig. 12). During the 1979 field season several of these were sampled with a fyke net (Photo 6), minnow traps, and by hook and line.

Figure 11. Electroshocking surveys in tributary streams of the proposed North Fork Snoqualmie reservoir.

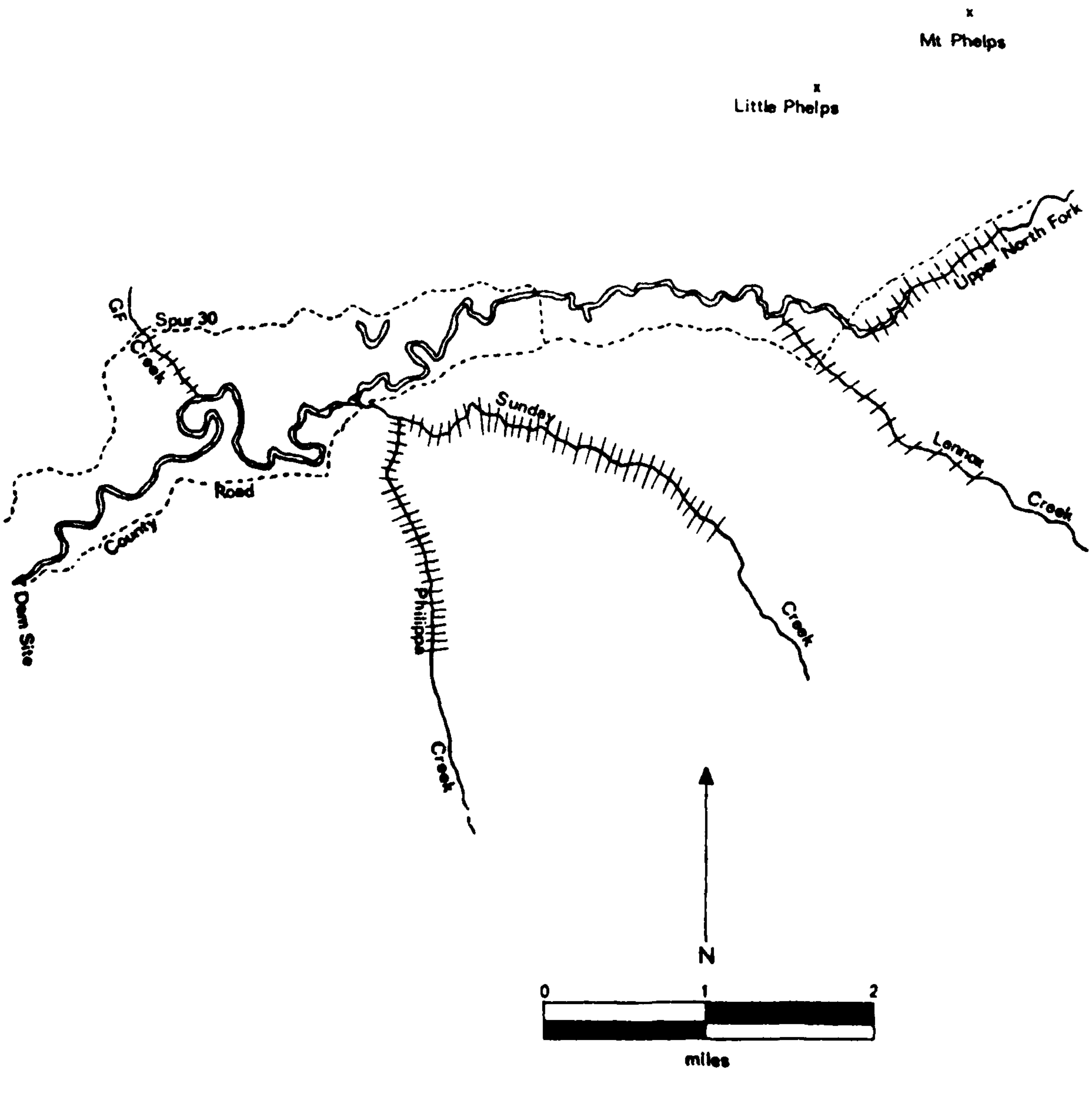


Photo 5. Measuring weight and length of a juvenile trout.

Figure 12. Systems of beaver ponds, bogs, and oxbow sloughs in the *North Fork Snoqualmie River* basin. The 1,530-foot elevation contour is shown. Systems are numbered 1 through 32.

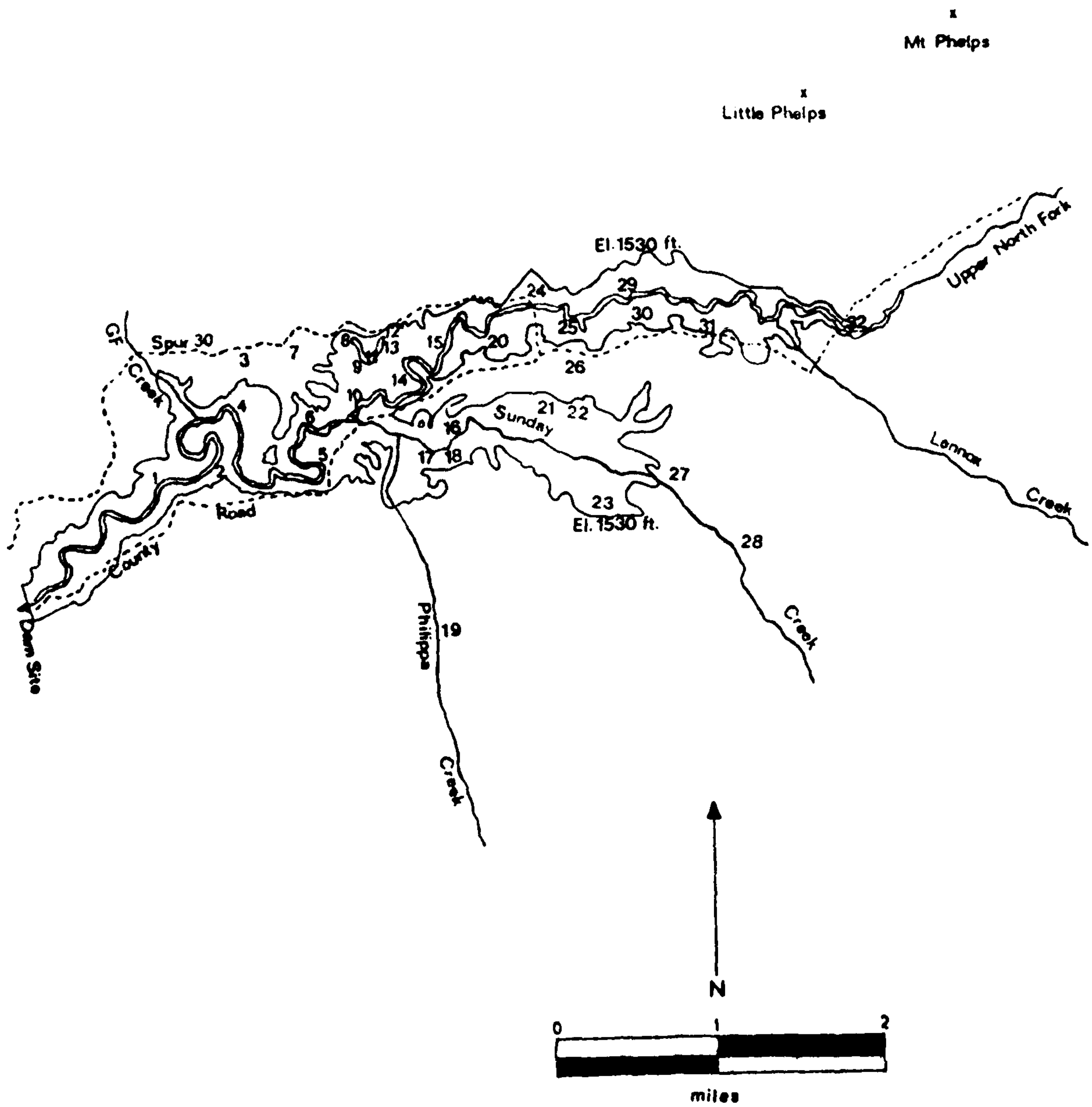


Photo 6. Sampling beaver pond fish populations with a fyke net.

We extensively trapped two beaver ponds in ponds-system numbers 17 and 24 with the fyke net and minnow traps and estimated trout populations in each. Chapman's modification of the Schnabel multiple census formula was used (Ricker 1975). Details of the 1979 pond sampling program were presented in our 1980 report (pp. 21 and 22).

From 3 June to 25 July 1980, we conducted a systematic hook and line survey of ponds in the North Fork Snoqualmie basin. Ponds were fished with a gold, size 0 (small), Mepps spinner when possible. In a few ponds with unusually dense vegetation or debris, a size 12, mosquito dry fly was used instead. We attempted to distribute fishing effort (number of casts) equally to all areas within a pond. No two casts were made to the same area. We tried to keep the total number of casts to each pond proportional to the size of each pond.

A successful cast was defined as one in which either a fish was caught, or one in which a fish struck at the lure but escaped. This reduced the bias against ponds with small fish which were less likely to get caught.

From our fyke netting and minnow trapping in 1979, we obtained trout population estimates for two beaver ponds in pond systems 17 and 24. In 1980 both ponds were also sampled with hook and line. The number of successful casts in these two ponds was compared to the number of successful casts made in other ponds in which the trout population was unknown. Assuming that the total number of casts in each pond was proportional to the area:

let $\hat{N}_i$ = trout population estimate in pond $i$

$\hat{n}_j$ = known trout population estimate in pond $j$

$\hat{c}_i$ = number of successful casts in pond $i$

$\hat{c}_j$ = number of successful casts in pond $j$.

then

$$\frac{\hat{n}_j}{C_j} (C_i) = \hat{N}_i$$

We combined data from two ponds with known trout population estimates to obtain a mean $\hat{n}_j$ and $\hat{c}_j$.

Trout caught by hook and line were identified to species and measured to fork length. Some scales were taken.

## Angler Creel Census

In 1979 we conducted a comprehensive creel census to assess angler effort, catch-per-unit-effort (CPUE), and total catch. Thirteen index areas were established for regular ground censusing (Fig. 13). Four of these were on the river downstream of the proposed dam site, and nine were upstream. Of the latter nine, one was on Fitchener Slough, and another was on a nearly oxbow slough. Details of the 1979 creel census were described in our 1980 report (pp. 23 to 27).

## Instream Flow

We studied instream flow requirements of fish in the North Fork Snoqualmie River. The primary purpose was to determine suitable discharges which would provide optimum habitat for fish in the river below the proposed damsite. A secondary purpose was to allow comparisons of the amount and type of habitat in different river sections. We used the Instream Flow Group (IFG) incremental methodology developed by the Instream Flow Service Group of the U.S. Fish and Wildlife Service (Bovee and Milhous 1978). It is called the incremental method because it evaluates effects of incremental changes in discharge. The IFG method quantifies potential habitat for a particular fish species at a particular life history stage, in a particular reach of stream, at different discharges.

The method has four major parts:

1. Collection of basic hydraulic data from the stream.
2. Computer hydraulic simulation of the stream at different discharges.
3. Selection of preferred depth, velocity, and substrate criteria for a species at a particular life history phase.
4. Computer calculation of habitat (weighted useable area) at different discharges by combining the hydraulic simulation (number 2) with the known species criteria.

Three instream flow stations were established for detailed hydraulic investigation. Two stations were below the proposed North Fork damsite (Fig. 14). One was at Wagner Campground and the other below Spur 10 bridge. The third station was upstream of the proposed damsite at Mt. Phelps Campground. Stations were chosen to represent major sections of river. Station 1 near Spur 10 bridge typified much of the river between RM 4.7 and RM 10.3. Station 2 at Wagner Campground represented much of the river between RM 10.3 and 13.0. Station 3 typified large sections of river between RM 18.2 an 20.0. For a habitat description of the river in these areas see our 1980 report (pp. 31 to 43).

Figure 13. Creel census sites in the North Fork Snoqualmie River system.

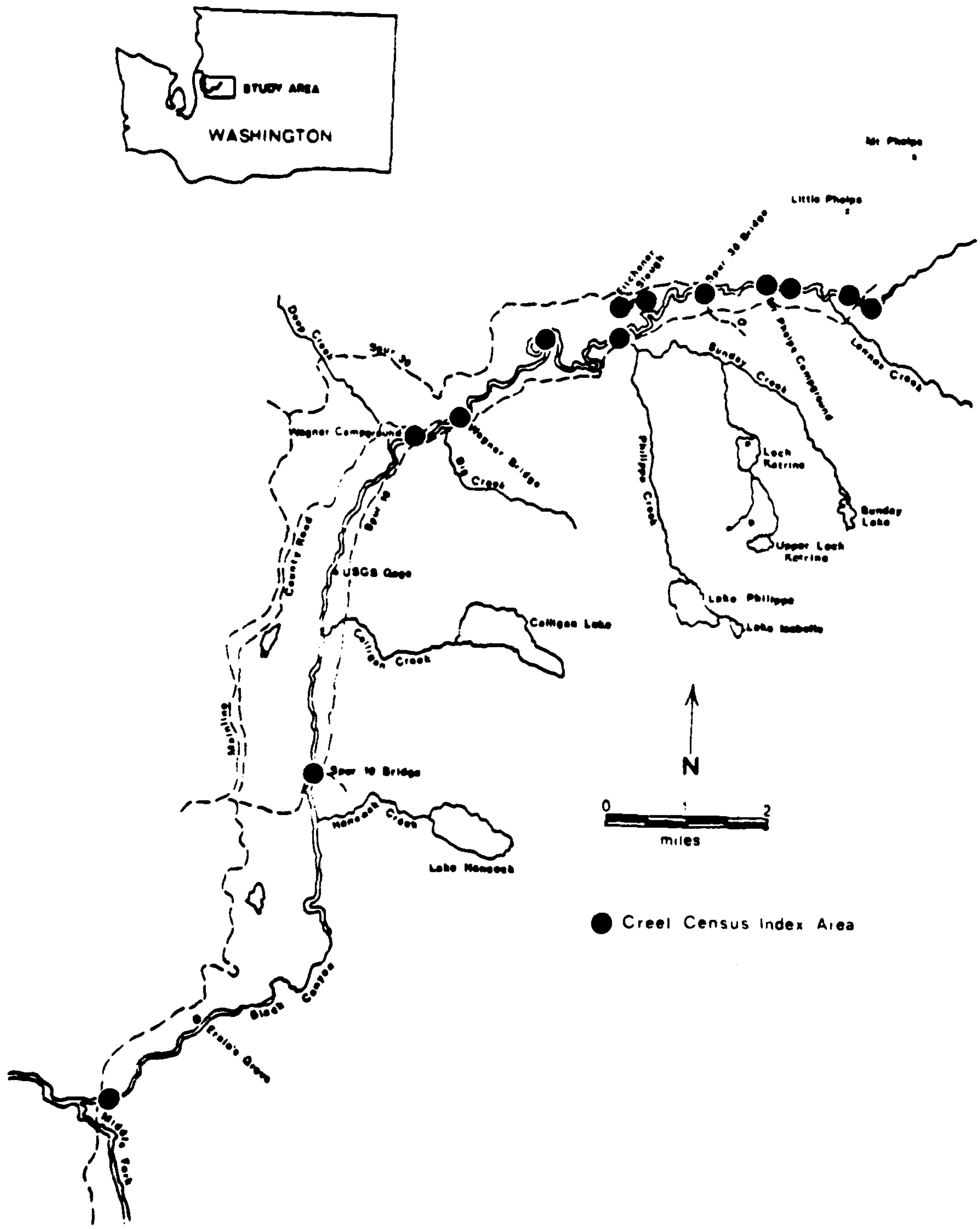
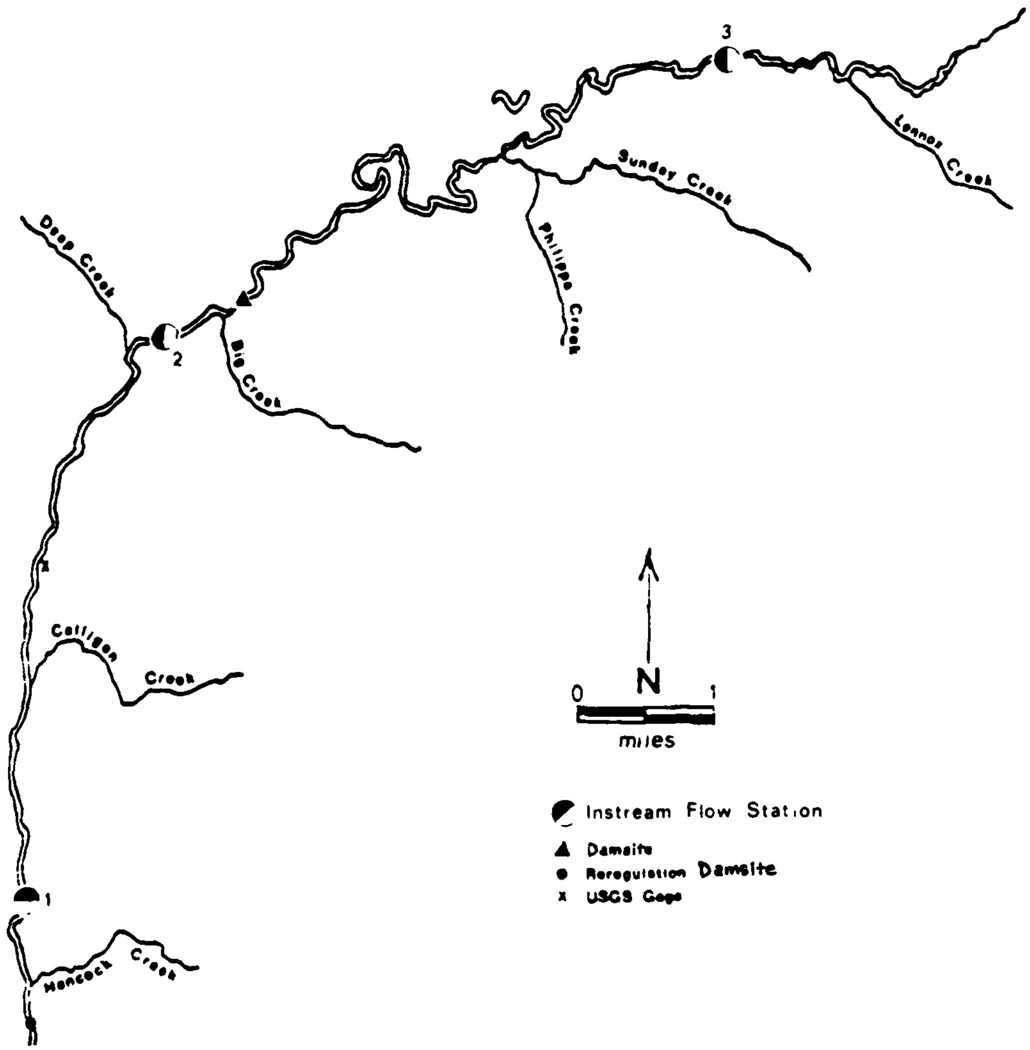


Figure 14. Instream flow measurement sites in the North Fork Snoqualmie River.



At each station three transects were installed perpendicular to the current. Each transect was located to delineate discrete areas of the stream cross section. A permanent benchmark was established and we installed two headstakes on opposing banks at each transect. The exact elevation relationship between the benchmark and headstakes was determined with an automatic level and a level (stadia) rod.

Between 18 and 30 measurements of velocity, depth, and substrate were made at each transect depending on its width. Each measurement point was called a vertical and was surveyed by wading or by boat. A 2.4-m (8-ft) boat was tethered to a steel cable secured to each bank (Photo 7). The procedures used were:

1. A wire tagline was stretched taut from headstake to headstake across the transect.

2. The distance from the headstake to the wetted stream perimeter was measured.

3. Depth and mean velocity were measured at each vertical with a Price AA current meter on a top-setting wading rod. Substrate type and particle size were recorded. This procedure was repeated across the transect.

4. The water surface elevation relative to the benchmark was measured with the automatic level and level rod (Photo 8) at each transect.

5. Procedures 1 to 4 were repeated at each instream flow station for three different discharges.

Raw data collected were then entered into the computer. IFG4 was the hydraulic computer program which used these raw data to simulate river conditions (depths and velocities) at flows not actually measured.

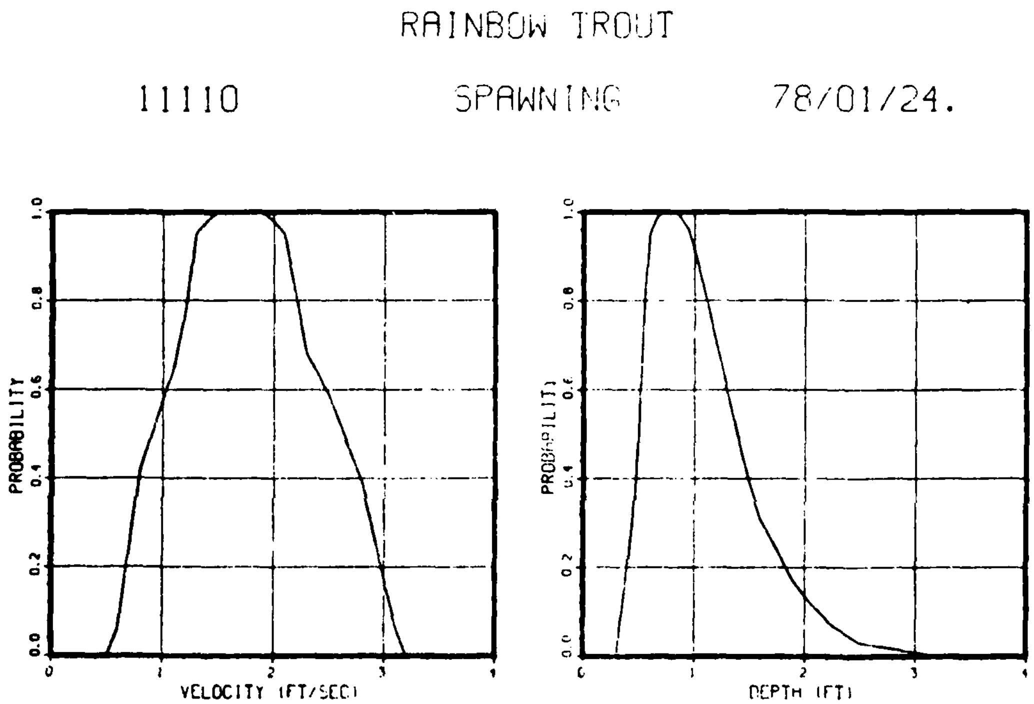
We then selected probability-of-use curves (criteria) for depth, velocity, and substrate, for each species and life stage of fish (Bovee 1978). These curves are derived from measurements and natural history observations made in the field. They are based on the assumption that individuals of a species will tend to select the most favorable conditions in a stream, but they will also use less favorable conditions. Probability-of-use decreases as conditions become less favorable. For example, the probability that rainbow trout will spawn in water with a velocity greater than 3-ft per second is less than 0.2 (Fig. 15).

Lastly, the HABITAT computer program compares the probability-of-use curves to the hydraulic simulation of IFG4. It then prints tables of fish habitat (weighted useable area per 1000 feet of stream) versus discharge for each fish species and life stage requested.

Photo 7. Measuring river depth and velocity from a boat at instream flow station 1.

Photo 8. Measuring water surface elevation with an automatic level and level rod.

Figure 15. Probability-of-use curves for rainbow trout spawning.



## RESULTS AND DISCUSSION

### Habitat Type Mapping

We constructed habitat maps of the North Fork Snoqualmie River based upon the river's physical characteristics and the percent of the streambank vegetated. They illustrated kinds, amounts, and spatial relationships of potential fish habitat in the river. We used them as aides in designing other biological studies.

A 3.0 to 4.6-m (10 to 15-ft) waterfall in Black Canyon (Photo 9) at RM 3.1 is a major migration barrier preventing upstream movement of several fish species. Two smaller falls upstream near Big Creek may also be upstream barriers. Details of the river habitat survey were presented in our 1980 report (Kurko et al. 1980, pp. 31 to 44).

Some of the river's presently unvegetated banks will eventually grow over and be stabilized. However, in places where the river is undercutting its banks, soil, and vegetation will continue to slide off. We observed this when we compared Weyerhauser's 23-year-old photos of the river with more recent ones. One particular sand slide near RM 12.9 (Photo 10) has considerably less vegetation now than it did in 1958.

GF Creek flows into the North Fork Snoqualmie River near RM 14.2 (Fig. 16). We surveyed the part of it between Spur 30 road and the river. Its drainage area and discharge were the smallest of any tributary we surveyed. The lower half of this section of GF Creek is characterized by a moderate gradient with good pool-riffle conditions, sections of excellent spawning gravel (Photo 11), and overhanging vegetation . The substrate is mainly gravel with some cobble riffles. The deeper pools are usually associated with logs. A 1-m (3.3-ft) fall and migration barrier (Photo 12) is located in the vicinity of the proposed reservoir's low pool level. A big log across the stream creates this fall.

Directly upstream is a large scoured-out basin with bare mud banks. During periods of high water, mud probably erodes into the stream at this point. Except for this one area, riparian vegetation is abundant and often shades portions of the stream. Small log jams and brush piles provide excellent rearing areas for small trout.

Moderate amounts of large organic debris (logs and brush) can act as sediment traps and improve fish habitat by the creation of plunge pools (Bisson and Sedell, in preparation). Also consumer benthic organisms, which are near the base of the food chain in streams, are concentrated in what Meehan et al. (1977) called "wood-created habitat". Streams west of the Cascade crest historically contained high natural levels of debris (Swanson et al. 1976). The biological characteristics of these streams evolved in response to this heavy load of organic

Photo 9. A 3.0 to 4.6-m (10 to 15-ft) waterfall and upstream migration barrier in Black Canyon at RM 3.1.

Photo 10. Sand slide on the North Fork Snoqualmie River near RM 12.9.

Figure 16. GF Creek

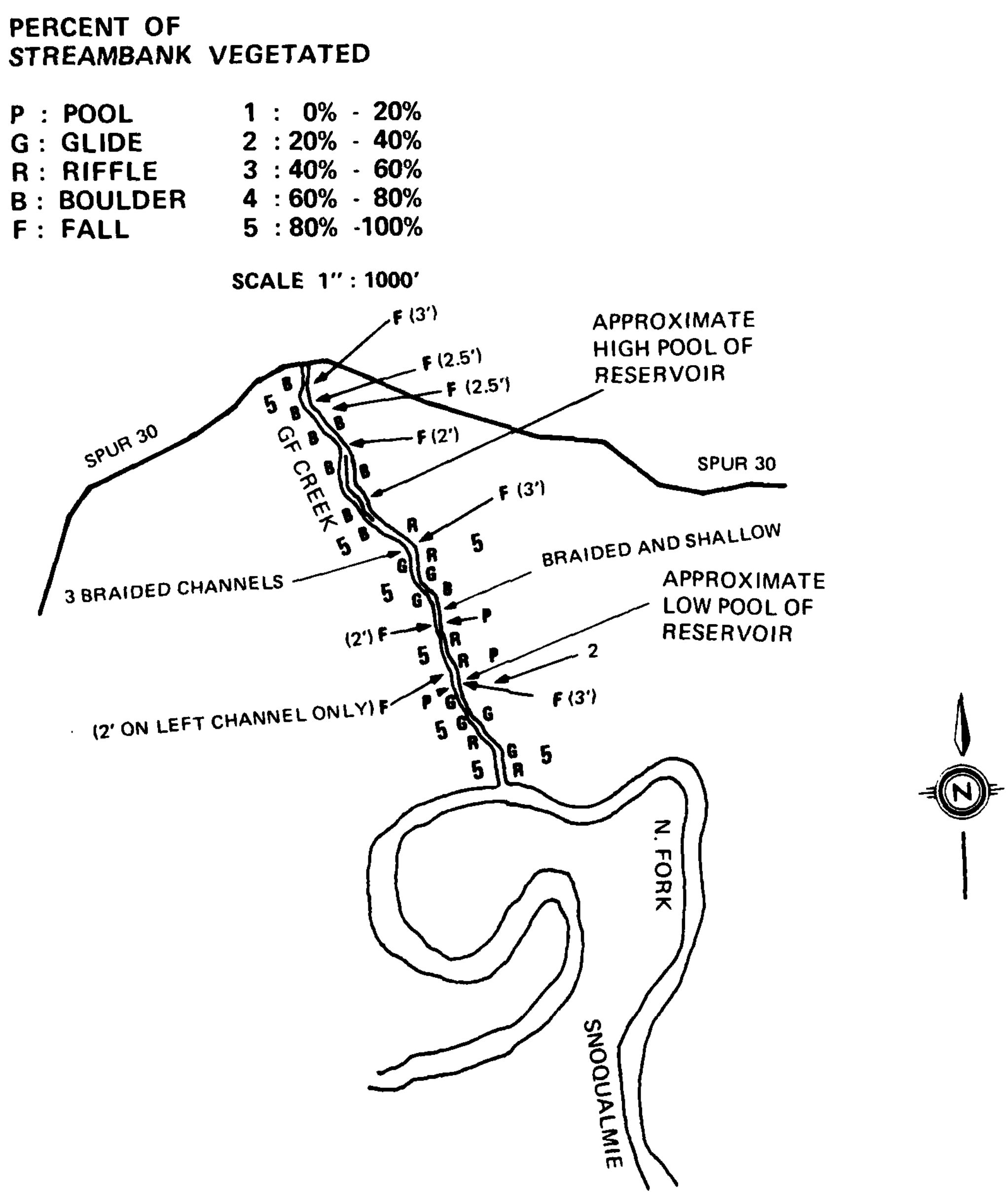


Photo 11. Spawning riffles along lower GF Creek.

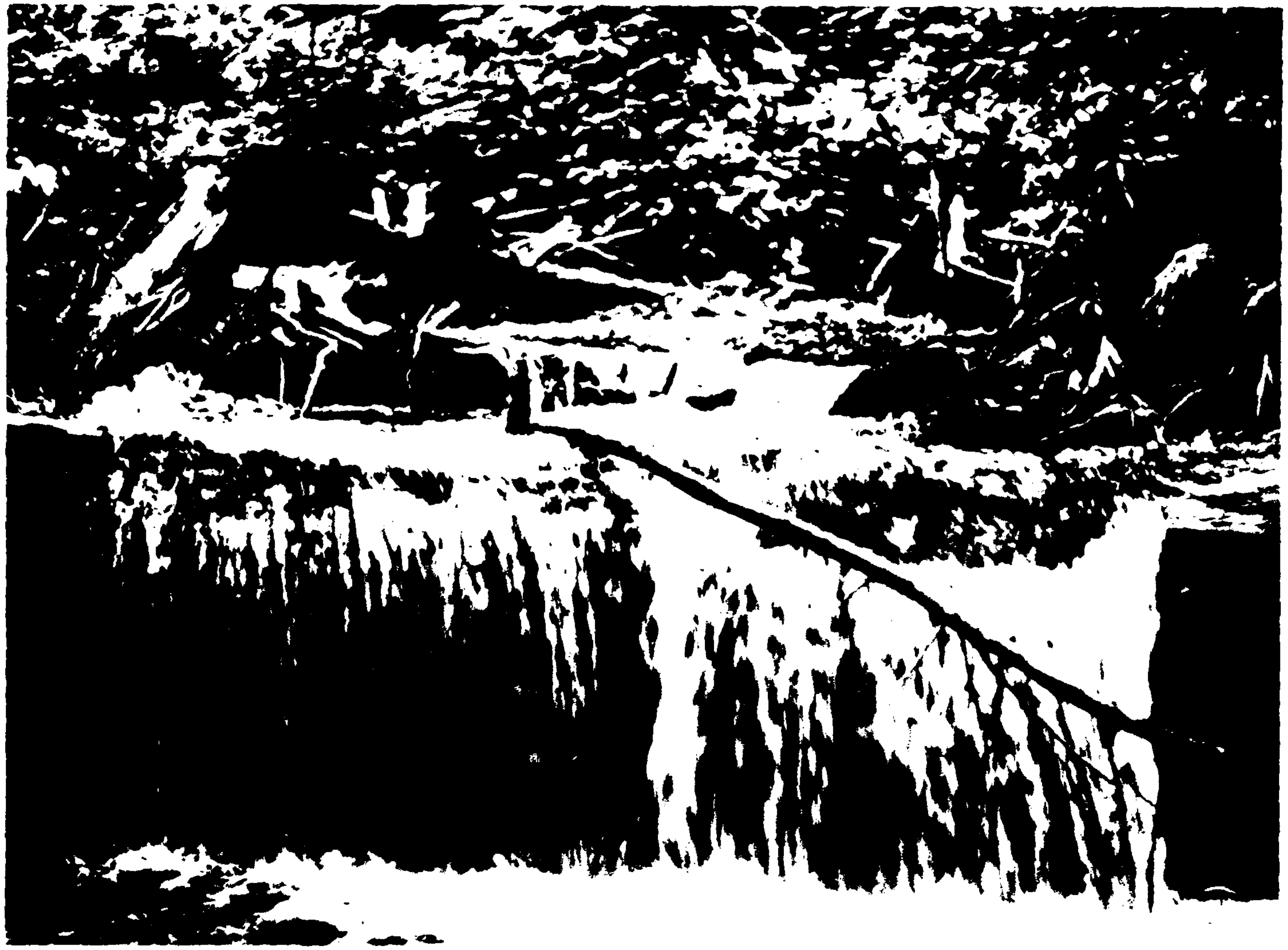


Photo 12. A 1-m (3.3-ft) fall and possible migration barrier on lower GF Creek.

debris in ways which are only now being studied (Swanson and Lienkaemper 1978).

The upper half of GF Creek below Spur 30 road has a steep mountainous character with numerous boulder areas, rapids, small falls, and a few pools (Photo 13). This is the portion of the stream that would be above the proposed reservoir's high pool elevation. The only spawning areas are some small pockets of patch gravel. Rearing areas for juvenile trout are similarly scarce, although some pools provide habitat for adults. Upstream spawning migrations would be difficult for all but the largest trout. Above Spur 30 road, GF Creek consists of a series of cascades and falls that allows no upstream migration and provides poor fish habitat.

Sunday Creek flows into the North Fork Snoqualmie River at RM 16.4 (Fig. 17). From its mouth, upstream to the proposed reservoir's high pool level, it is characterized by a gentle to moderate gradient. This section has good pool-riffle conditions and contains excellent areas for trout spawning and rearing. The bottom is mainly cobble and gravel. Some of the best trout cover in this stream section are the numerous large stumps in many of the pools.

The next mile of Sunday Creek, above the reservoir's high pool level, extends upstream to just beyond the uppermost bridge (Fig. 17). The most distinctive features of this section are the wide braided channel and lack of overhanging riparian vegetation. While the streambanks themselves are densely vegetated, the broad braided channel (up to several hundred feet wide) usually keeps the vegetation well back from the water's edge, except during periods of high flow (Photo 14).

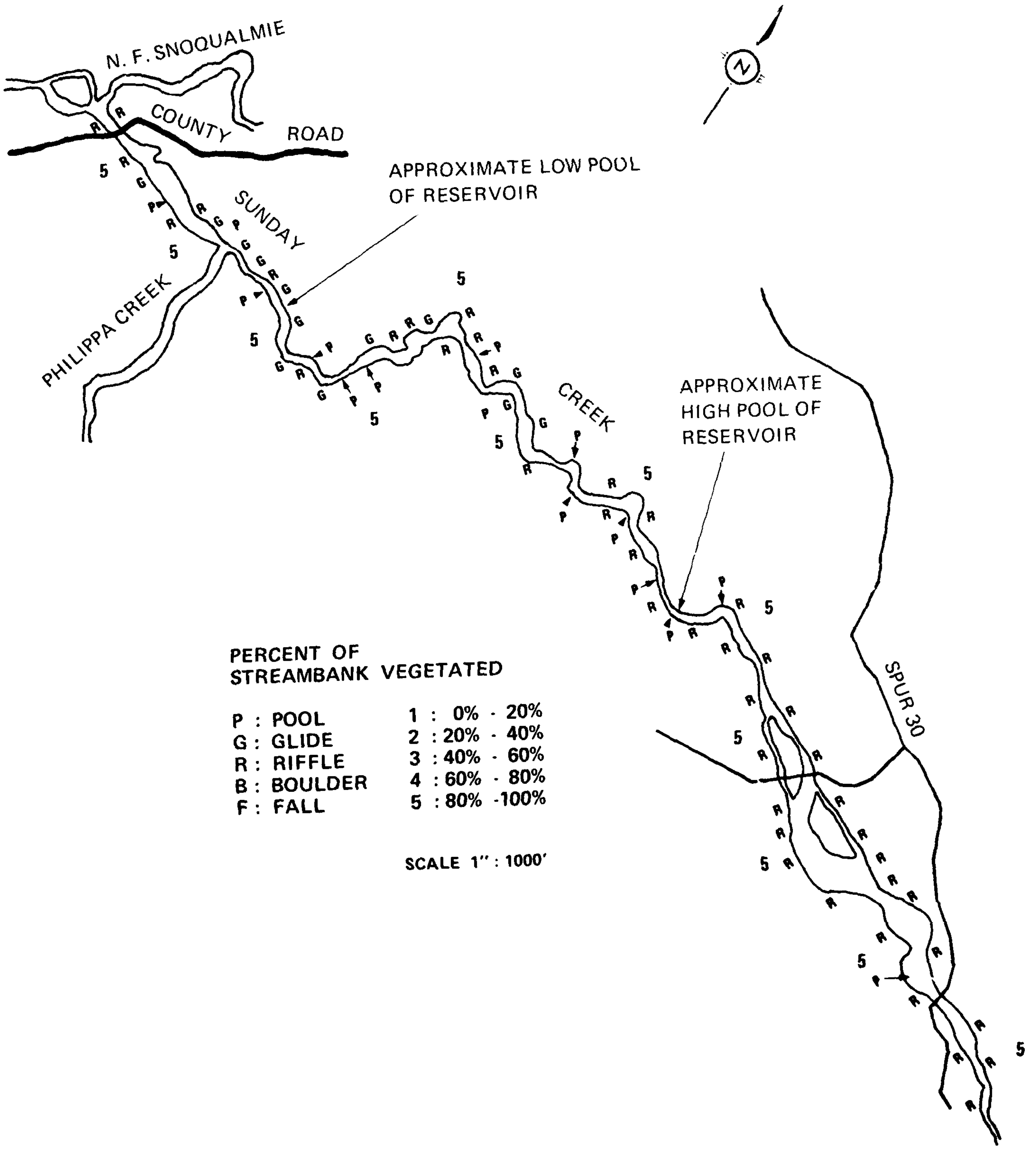
Overhanging streamside vegetation strongly influences the quality of habitat for coldwater fishes (Meehan et al. 1977). It provides shade, preventing adverse water temperature fluctuations. The roots of trees, shrubs, and herbaceous vegetation stabilize streambanks and provide cover in the form of overhanging banks. Riparian vegetation acts as a "filter" to prevent sediment and debris from entering the stream. It directly influences the food chain of the stream ecosystem by shading the water and providing organic detritus and insects for stream organisms. Overhanging vegetation also provides cover for fish. Loss of this low cover, especially over pools, decreases the quality of rearing habitat for juvenile salmonids (Bustard and Narver 1975).

The stream in this section is characterized almost exclusively by gravel or cobble riffles and few pools. Instream cover for juvenile trout in the form of logs or boulders is rare.

Philippa Creek flows into Sunday Creek about 0.25 mile above the latter's confluence with the North Fork Snoqualmie River (Fig. 18). The proposed reservoir's low pool level would not inundate any of Philippa Creek. The reservoir's high pool level would be just above Spur 16

Photo 13. Upper GF Creek.

Figure 17. Sunday Creek



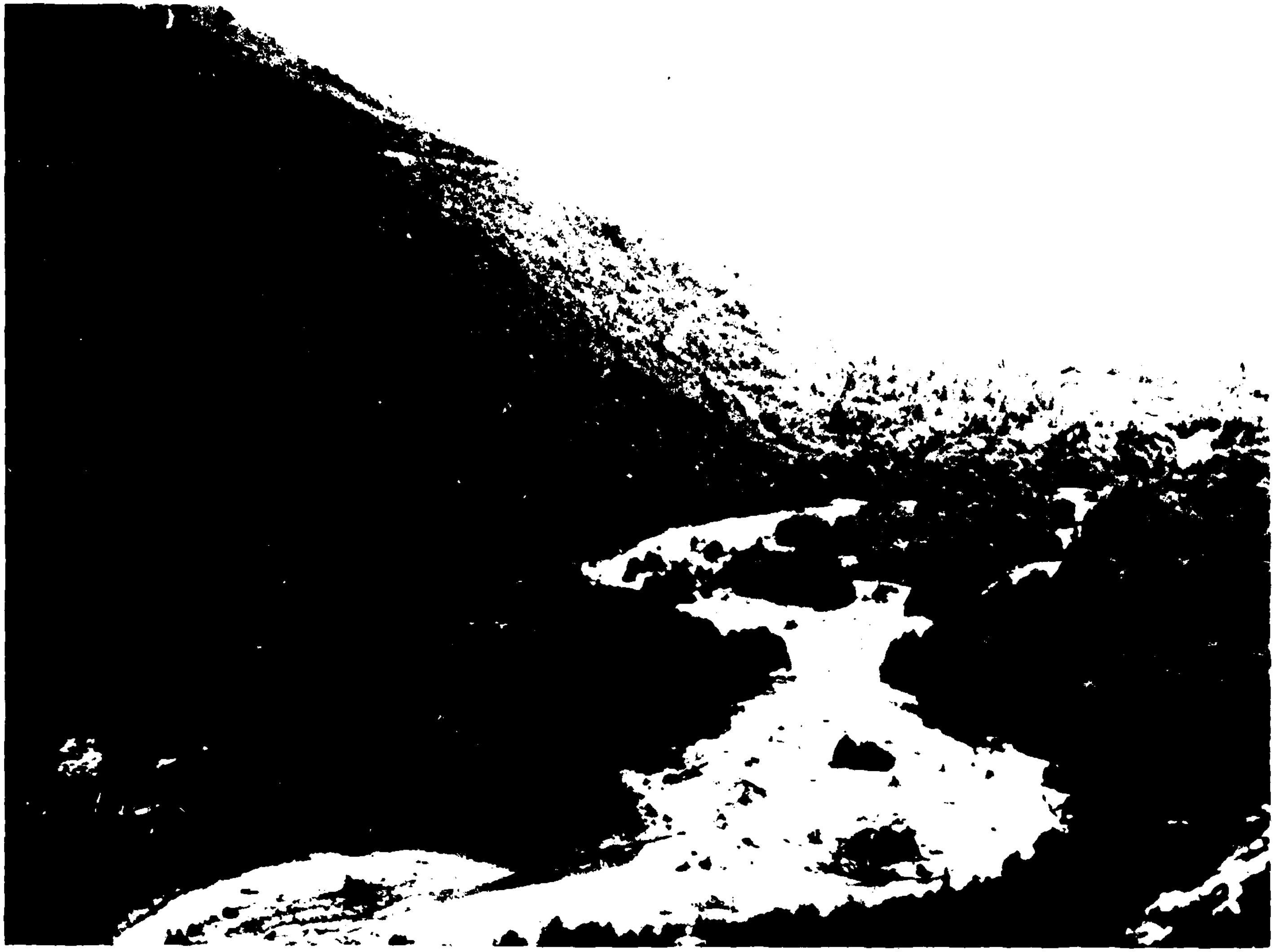
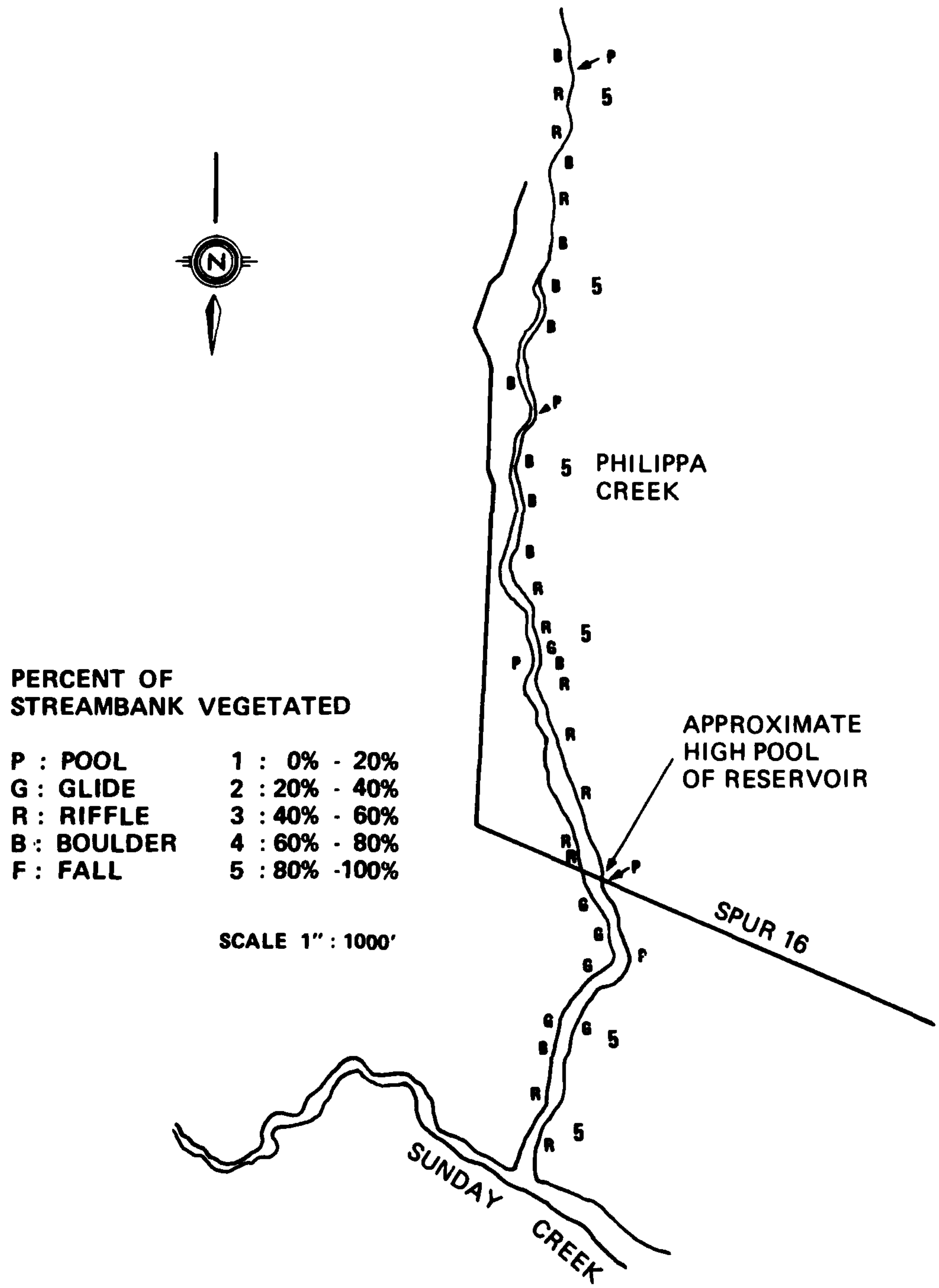


Photo 14. Upper Sunday Creek, showing wide braided channel area.

Figure 18. Philippa Creek



bridge. This lower section of stream is characterized by a moderate gradient, riffles and glides, and a cobble or gravel bottom. It contains several good areas for trout spawning and rearing. Numerous submerged brush piles provide good instream cover. Riparian vegetation sometimes overhangs the stream (Photo 15).

The next 1.25 miles of creek are dominated by rapids and continual boulder areas (Photo 16). In many cases riparian vegetation does not overhang the stream because of the wide channel. This is especially true within the first 0.5 mile upstream of Spur 16 bridge. Good spawning gravel occurs in the vicinity of Spur 16 bridge, but its presence is infrequent farther upstream. Large organic debris is less abundant than farther downstream.

Lennox Creek flows into the North Fork Snoqualmie River near RM 20.0 (Fig. 19). The proposed reservoir's high pool level would inundate only the lower 0.1 mile of this tributary. The most distinctive features of the lower 0.5 miles of Lennox Creek are the wide braided channel (Photo 17) and lack of overhanging riparian vegetation. As on upper Sunday Creek, the actual streambanks are densely vegetated, but the broad braided channel usually keeps the vegetation well back from the water's edge. We looked at old photos of Lennox Creek taken in 1958 just after the surrounding forest had been logged. The braided channel area was larger than it is now. Over the last 23 years, small areas have become revegetated, and undoubtedly will slowly continue to do so. The lower 0.5 mile of Lennox Creek is barren looking to a human observer (Photo 18). The substrate is mostly large cobble. Trout spawning and rearing areas are infrequent.

The next upstream mile of Lennox Creek is characterized by numerous boulder areas with frequent pools. One-half mile upstream from the first Forest Service bridge is a 1.2-m (4-ft) waterfall on the stream's left channel (Photo 19). One-half mile farther upstream is a long series of 0.6 to 1.2-m (2 to 4-ft) cascades which would be an upstream migration barrier to all but the largest trout (Photo 20). Some old growth timber still grows along the banks of this section of Lennox Creek. The channel here is not braided as it is downstream.

We surveyed the upper North Fork Snoqualmie River above the Forest Service road bridge (Fig. 20). The reservoir's high pool elevation would inundate about 0.15 mile of the upper river. The first 0.5 mile of river surveyed is characterized by a gentle gradient, good pool-riffle conditions, and excellent spawning gravel (Photo 21). Upstream of this section the gradient becomes steeper. Boulder-filled rapids are interspersed regularly with pools. Instream brush piles and log jams are frequent. The stream banks are usually covered with old growth forest. This upper section of river is a good juvenile trout rearing area. Distribution of spawning gravel is patchy but adequate.

Photo 15. Overhanging riparian vegetation along lower Philippa Creek.

Photo 16. Boulder area of upper Philippa Creek.

Figure 19. Lennox Creek

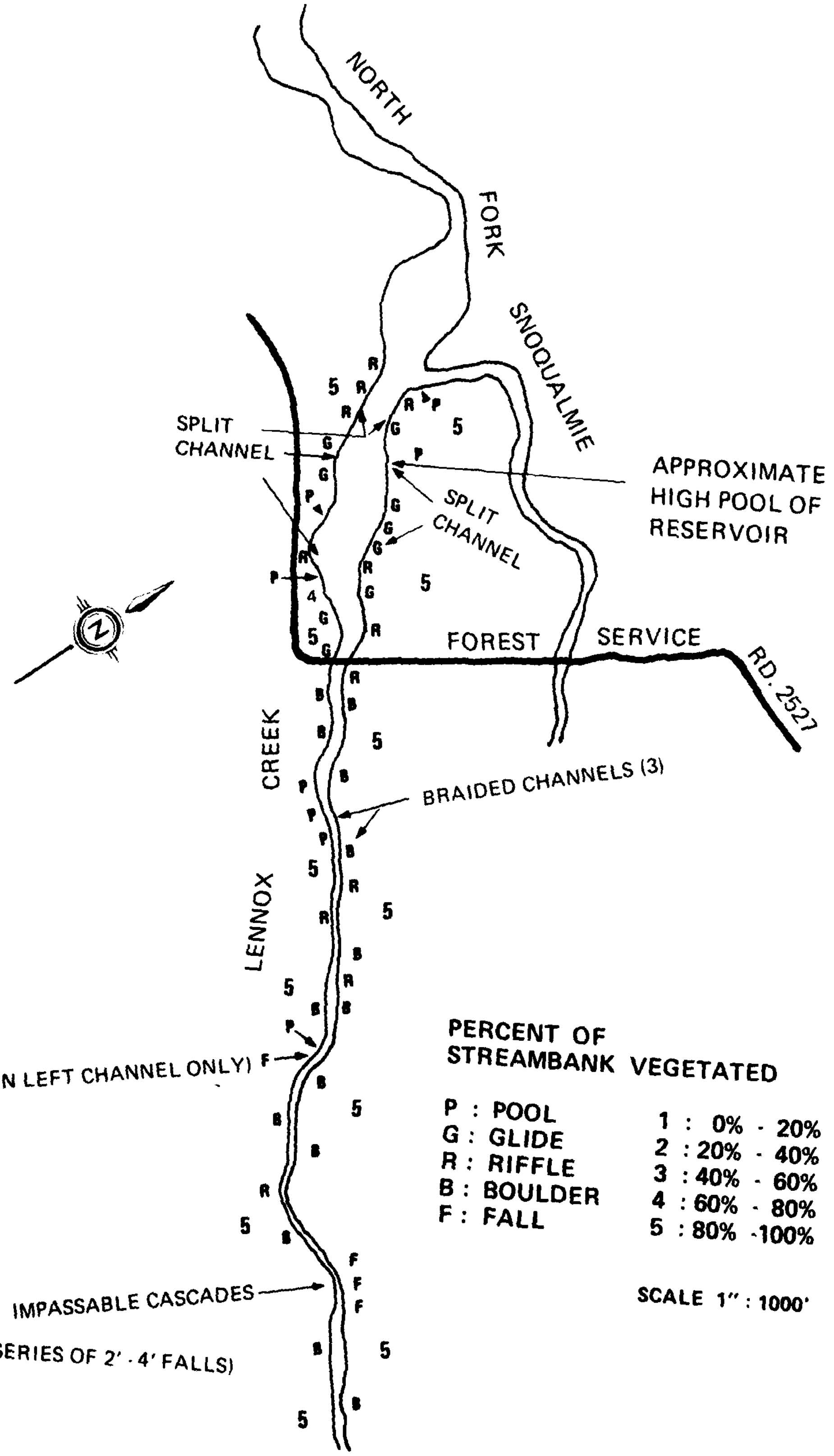


Photo 17. Braided channel area of lower Lennox Creek (top). Note the much narrower channel of the unlogged section of the upper North Fork Snoqualmie River (center).

Photo 18. Barren-looking lower Lennox Creek as seen from the most downstream Forest Service bridge.

Photo 19. A 1.2-m (4-ft) waterfall on the left channel of upper Lennox Creek.

Photo 20. Beginning of a long series of cascades on upper Lennox Creek which would probably be an upstream migration barrier to most reservoir trout. Steeper cascades directly upstream are not visible in this photo.

Figure 20. Upper North Fork Snoqualmie River

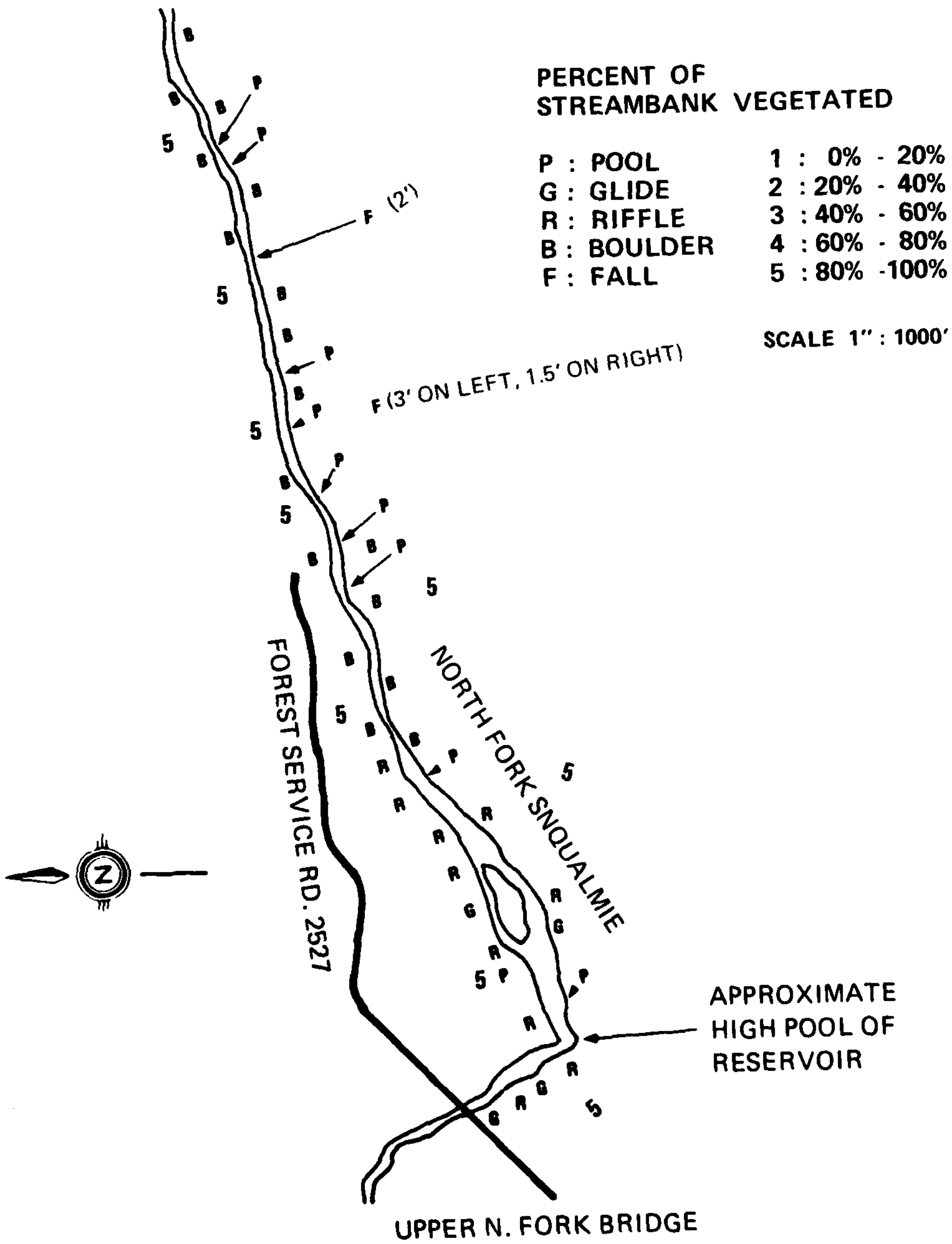


Photo 21. Upper North Fork Snoqualmie River near RM 21.
Note the excellent spawning riffles.

Results of our survey of beaver ponds, bogs, and oxbow sloughs are presented later in conjunction with pond fish studies.

## Water Quantity and Quality

We examined records of water quantity and quality of the North Fork Snoqualmie River to better understand and evaluate the river's habitat potential for aquatic life. These records also established an environmental baseline for comparisons with projected changes both downstream and upstream of the proposed dam.

In 37 years of records the river flows have averaged 506 cfs (USGS 1978). The COE water quality program (1980a) monitored discharge at the USGS gage at RM 9.2 (Fig. 21). For the period of record, a maximum flood discharge of 4,580 cfs occurred on 15 December 1979. The minimum discharge recorded was 44 cfs on 26 September 1979. River levels were higher during late summer of 1980 than they were during late summer of 1979.

The river at Wagner bridge was warmer than at the upper North Fork station (Figs. 22 and 23). Numerous beaver ponds between the two sites contribute warmer water. In addition, with the gentle gradient and sparse shade, solar radiation has a greater effect on this section of river.

Sunday Creek was warmer than either the upper North Fork or Lennox Creek (Figs. 23 to 25). This may be due to the presence of Sunday Lake. This lake is below 610 m (2,000 ft) in elevation and is 6.0 km (3.7 mi) from the mouth of Sunday Creek (Fig. 1, p. 10).

Conductivity was very low at the upper stations and slightly higher at Wagner bridge (Figs. 26 to 29). Conductivity is a measure of water's capacity to convey an electric current and is related to the concentration of ionized substances. Certain of these substances can be important for primary production. Conductivity increased as discharge decreased. One beaver pond was also sampled (Table 1). Its conductivity was much higher than in either the river or its tributaries. The numerous beaver ponds draining into the river probably helped increase the conductivity at Wagner bridge.

The pH values for all stations were usually between 6.6 and 6.9 (Table 1). Unusually high values (over 8.0 as recorded by COE) listed in our 1980 report (pp. 47 and 48) were caused by instrument error and were revised by COE. Dissolved oxygen in the river and its tributaries were always near or above saturation levels. Turbidity levels increased during winter and spring along with the increased precipitation and were highest at Wagner bridge. Total organic carbon levels acted similarly and peaked in March 1980 (Fig. 30). Phenolphthalein alkalinity was relatively low at all stations (Table 1).

Figure 21. North Fork Snoqualmie River hydrograph.

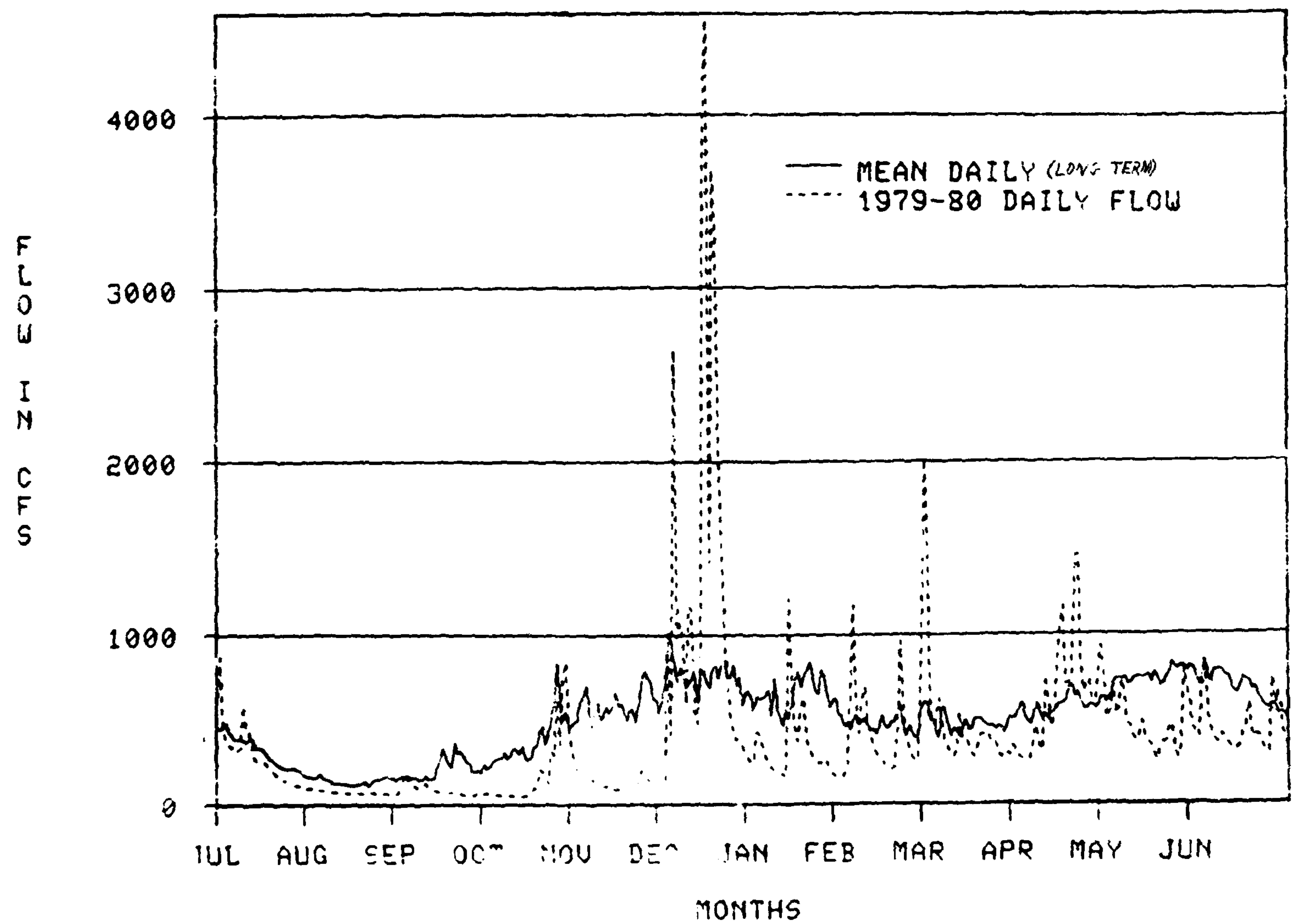


Figure 22. North Fork Snoqualmie River temperature at Wagner Bridge from the COE water quality sampling program.

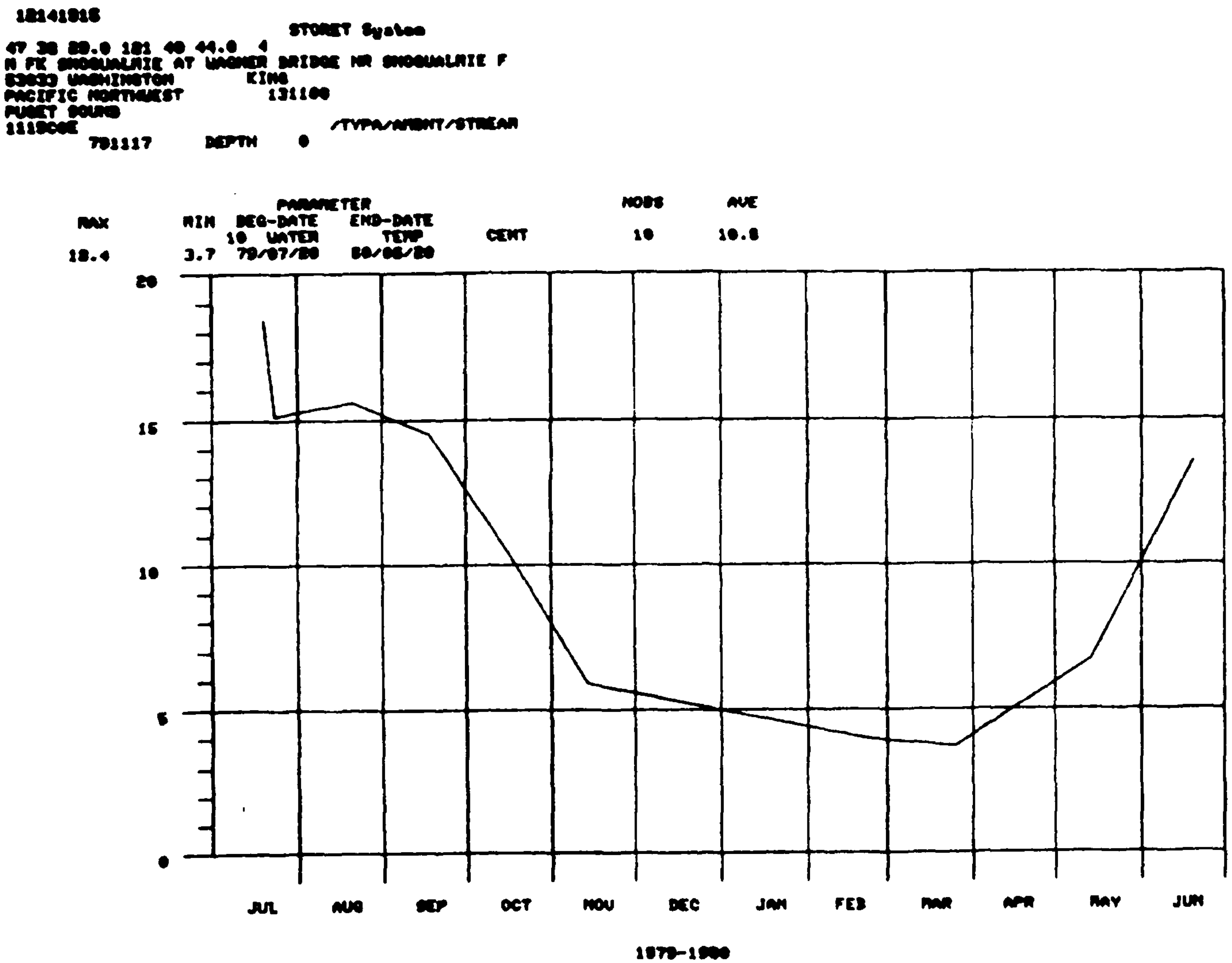


Figure 23. North Fork Snoqualmie River temperature at upper North Fork Bridge from the COE water quality sampling program.

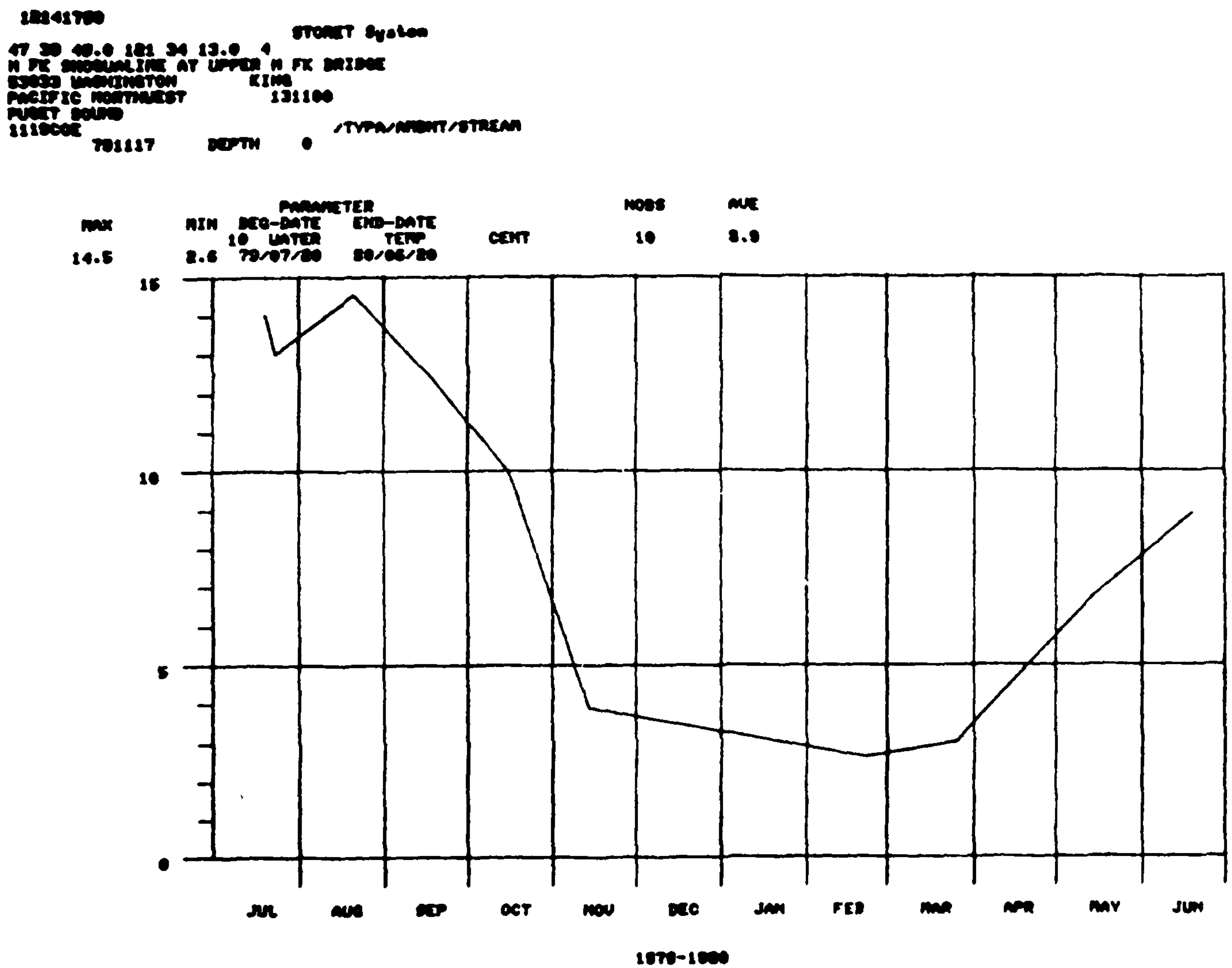


Figure 24. Sunday Creek temperature at County Road Bridge from the COE water quality sampling program.

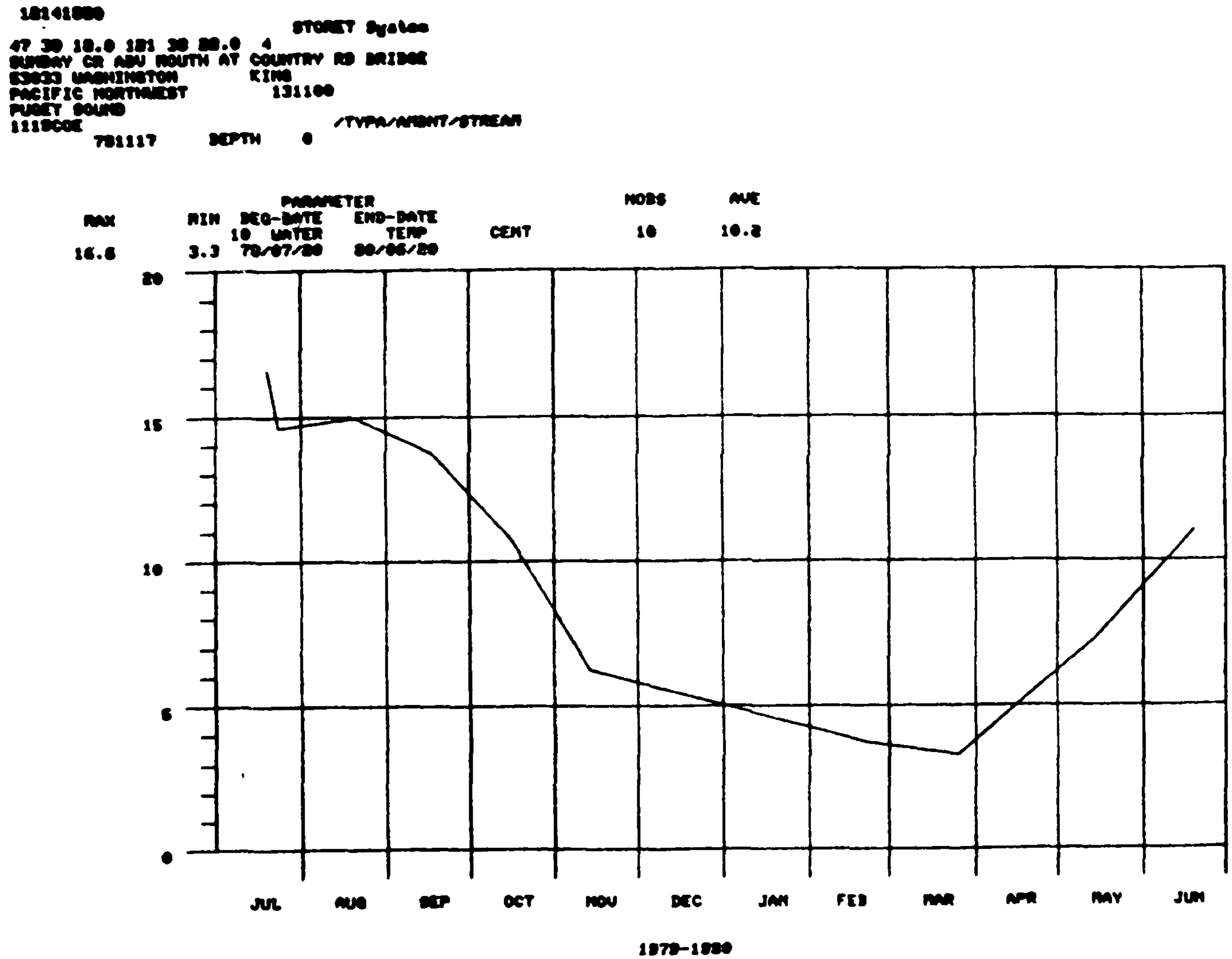


Figure 25. Lennox Creek temperature at County Road Bridge from the COE water quality sampling program.

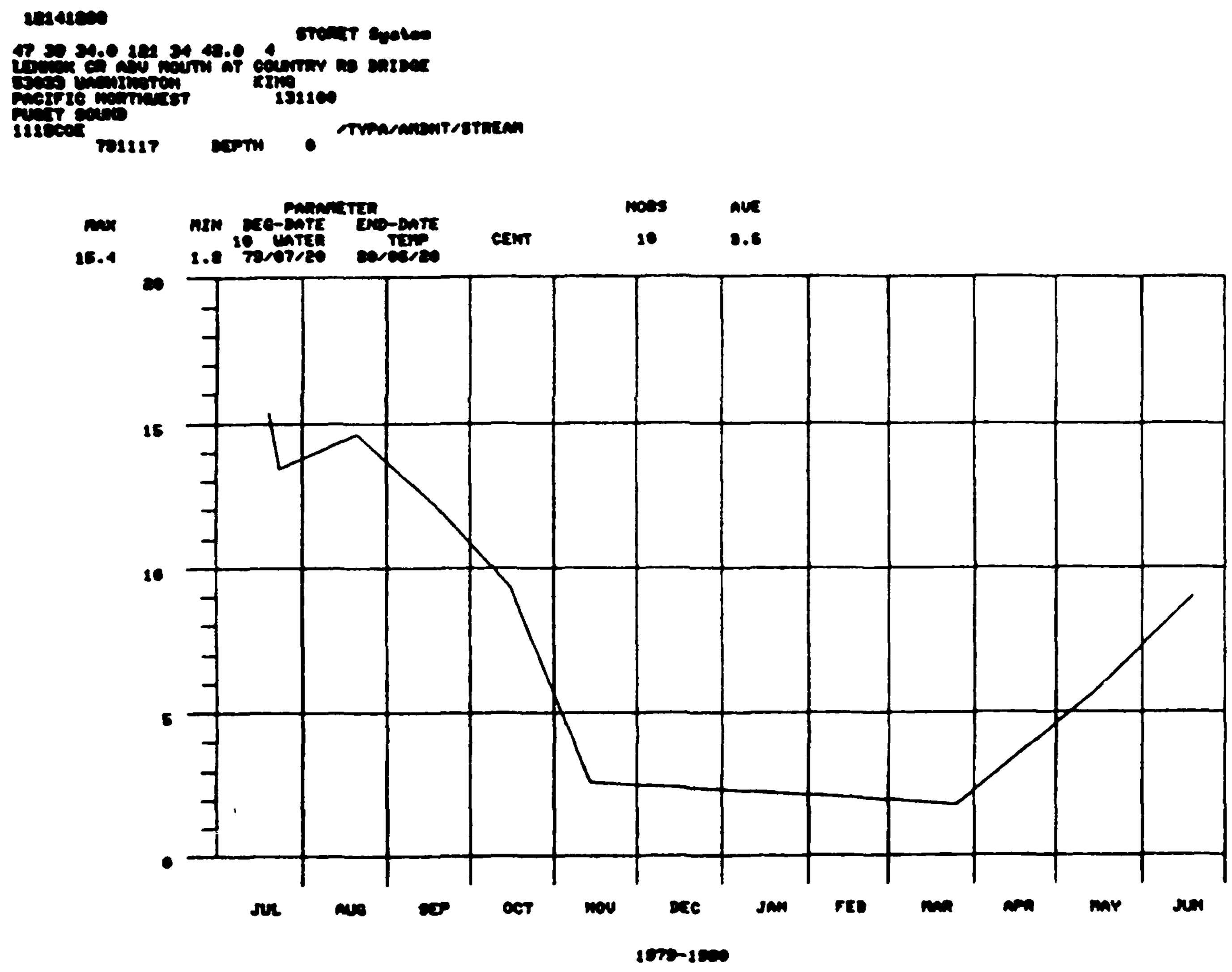


Figure 26. North Fork Snoqualmie River conductivity at upper North Fork Bridge from the COE water quality sampling program.

```
12141780
                              STORET System
47 30 40.0 121 34 1?.0  4
N FK SNOQUALMIE AT UPPER N FK BRIDGE
53033 WASHINGTON        KING
PACIFIC NORTHWEST        131100
PUGET SOUND
1119COE                          /TYPA/AMBNT/STREAM
        791117     DEPTH    0

                PARAMETER                               NOBS     AVE
MAX        MIN  BEG-DATE   END-DATE
               95 CNDUCTVY   AT 25C    MICROMHO          10       17
36          10  79/07/20   80/06/20
```

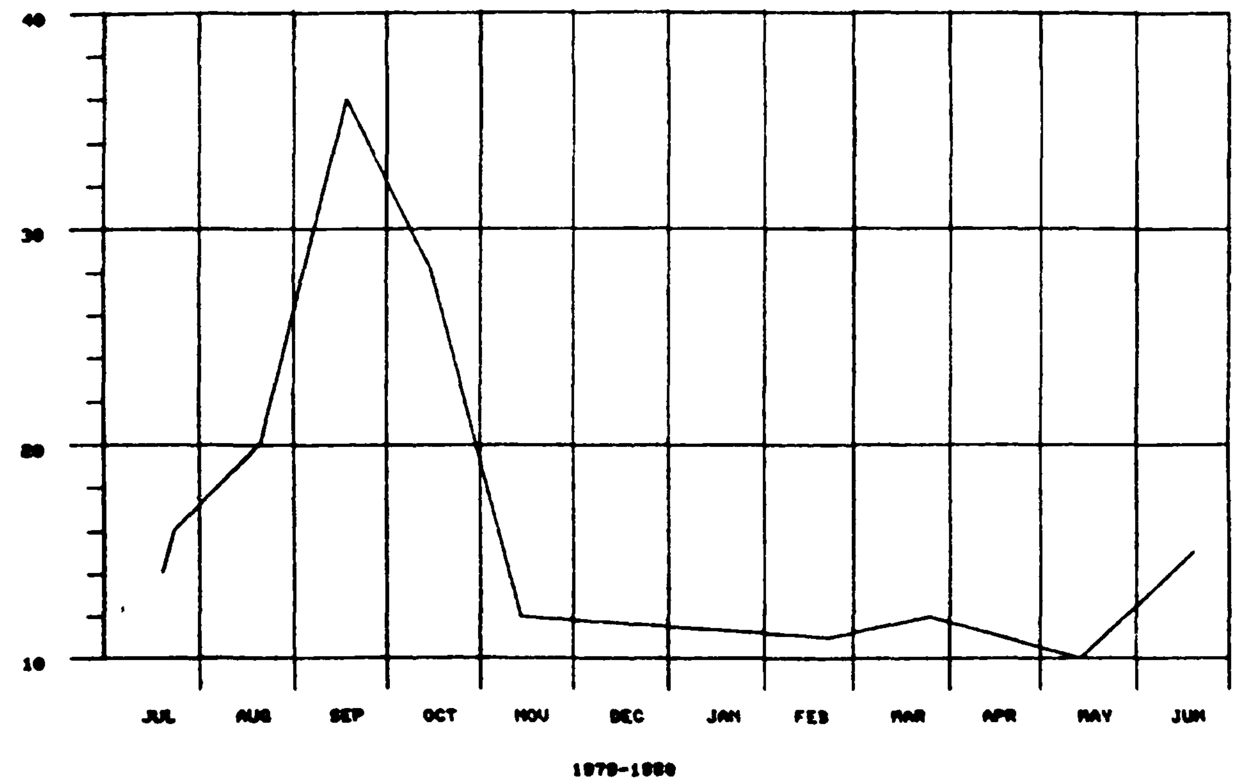


Figure 27. Lennox Creek conductivity at County Road Bridge from the COE water quality sampling program.

```
12141300
                          STORET System
47 38 34.0 121 34 48.0  4
LENNOX CR ABV MOUTH AT COUNTRY RD BRIDGE
53033 WASHINGTON          KING
PACIFIC NORTHWEST           131100
PUGET SOUND
1119COE                          /TYPA/AMBNT/STREAM
        781117     DEPTH    0

                  PARAMETER                             NOBS     AVE
    MAX       MIN  BEG-DATE   END-DATE
                  95 CNDUCTVY   AT 25C   MICROMHO          9        15
    30          8  79/07/20   80/06/20
```

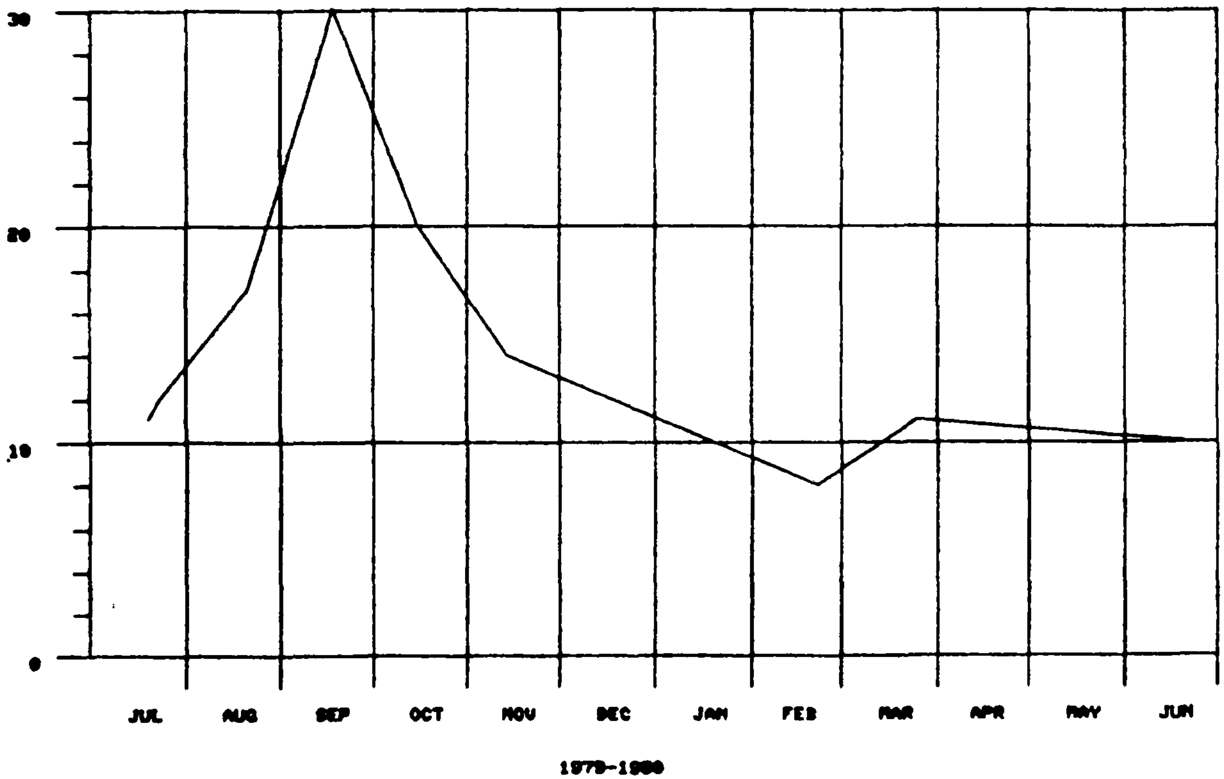


Figure 28. Sunday Creek conductivity at County Road Bridge from the COE water quality sampling program.

```
 18141880
                                STORET System
47 38 18.0 121 38 88.0  4
SUNDAY CR ABU MOUTH AT COUNTRY RD BRIDGE
53033 WASHINGTON        KING
PACIFIC NORTHWEST         131100
PUGET SOUND
1119COE                          /TYPA/AMBNT/STREAM
       791117      DEPTH     0

                        PARAMETER                            NOBS      AVE
 MAX           MIN  BEG-DATE    END-DATE
                    95 CNDUCTVY    AT 25C    MICROMHO          9        16
  28            10  79/07/20    80/06/30
```

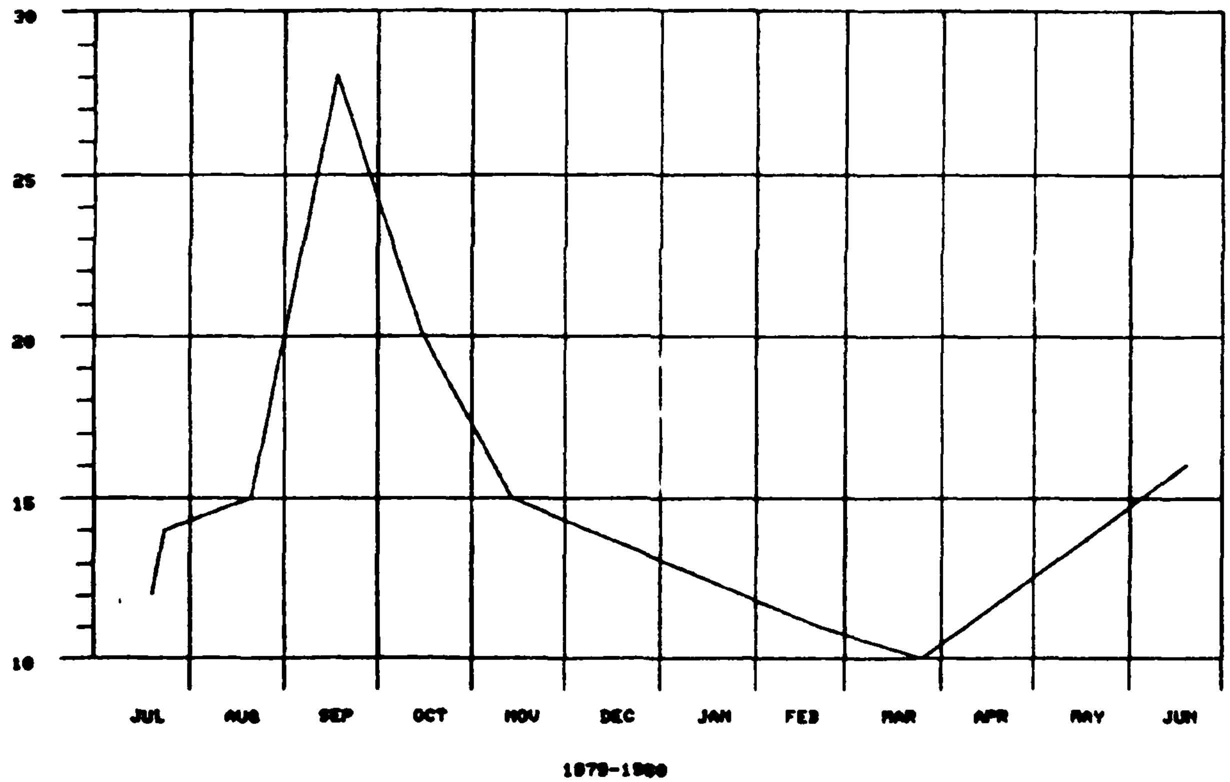


Figure 29. North Fork Snoqualmie River conductivity at Wagner Bridge from the COE water quality sampling program.

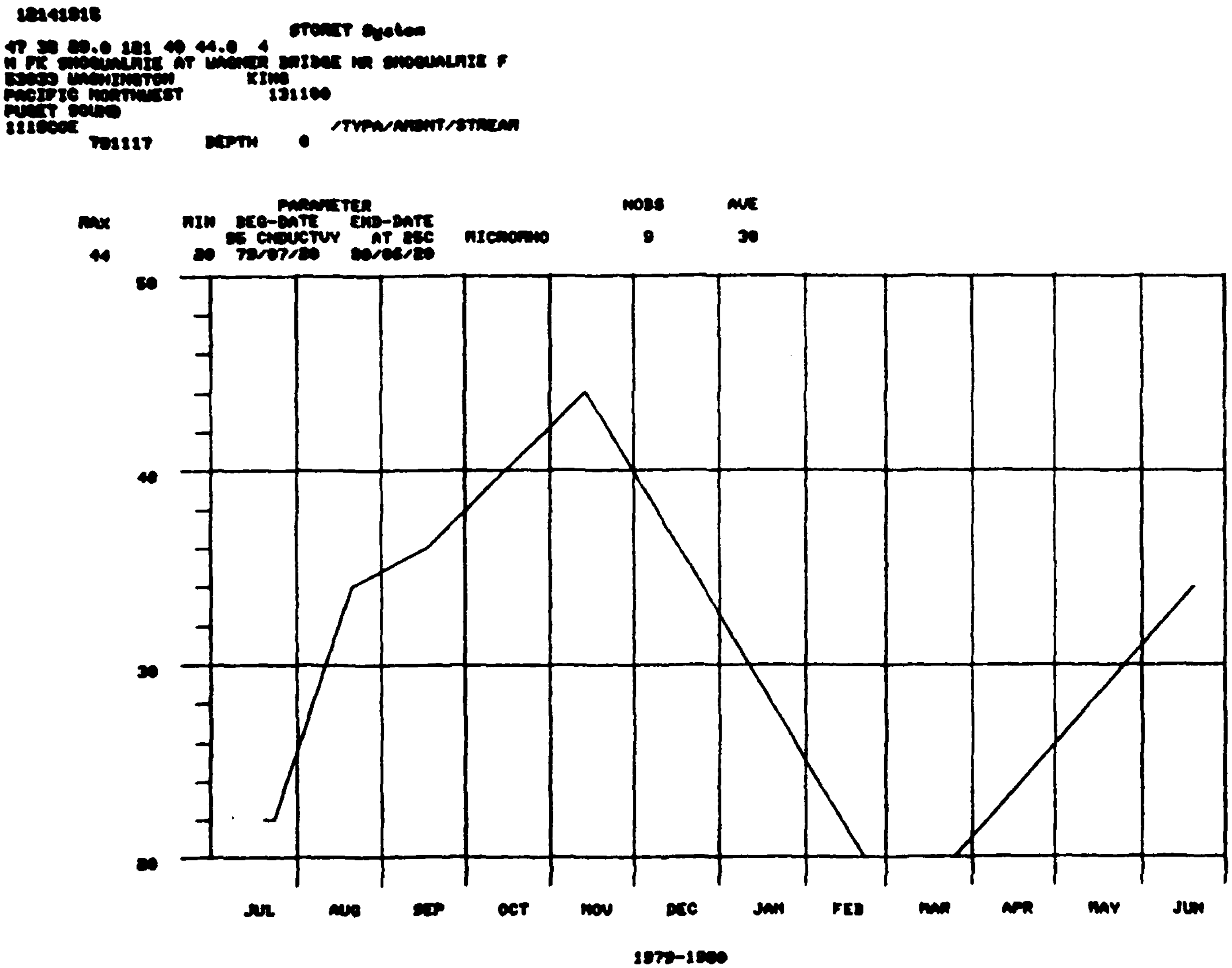


Table 1. Water quality data from the COE North Fork Snoqualmie River sampling program.

| Date | Water temp. Cent. | Conductivity at 25°C micromho | pH | DO MG/L | DO satur. percent | Turbidity trbidmtr hach FTU | Phenolphthalein alk MG/L |
|---|---|---|---|---|---|---|---|
| 12141750 | | | | | | | |
| 47 39 49.0 121 34 13.0 4 Station 4 | | | | | | | |
| N. Fk Snoqualmie at upper N. Fk. Bridge | | | | | | | |
| 79/07/20 | 14.0 | 14 | 6.95 | 9.2 | 94.0 | -- | |
| 79/07/24 | 13.0 | 16 | -- | 9.9 | 99.1 | -- | -- |
| 79/08/21 | 14.5 | 20 | -- | 10.4 | 107.7 | -- | 9 |
| 79/09/18 | 12.4 | 36 | -- | 10.3 | 101.9 | 0.1 | 8 |
| 79/10/16 | 10.0 | 28 | -- | 10.2 | 94.9 | 0.2 | 8 |
| 79/11/14 | 3.9 | 12 | -- | 12.8 | 102.7 | 0.4 | 7 |
| 80/02/22 | 2.6 | 11 | 6.60 | 14.0 | 109.1 | 0.3 | 4 |
| 80/03/26 | 3.0 | 12 | 6.80 | 14.5 | 114.5 | 0.4 | 4 |
| 80/05/14 | 6.7 | 10 | 6.70 | 11.0 | 97.3 | 0.4 | 4 |
| 80/06/20 | 8.9 | 15 | 6.61 | 11.8 | 107.2 | 0.2 | 2 |
| 12141800 | | | | | | | |
| 47 39 34.0 121 48.0 4 Station 3 | | | | | | | |
| Lennox Cr. above mouth at County Road Bridge | | | | | | | |
| 79/07/20 | 15.4 | 11 | 6.91 | 9.5 | 100.0 | -- | -- |
| 79/07/24 | 13.4 | 12 | -- | 10.2 | 102.9 | -- | -- |
| 79/08/21 | 14.6 | 17 | -- | 10.9 | 113.1 | -- | 7 |
| 79/09/18 | 12.2 | 30 | -- | 10.8 | 106.4 | 0.1 | 7 |
| 79/10/16 | 9.3 | 20 | -- | 11.0 | 100.3 | 0.1 | 6 |
| 79/11/14 | 2.6 | 14 | -- | 13.8 | 107.1 | 0.1 | 6 |
| 80/02/22 | 2.0 | 8 | 6.60 | 14.6 | 111.9 | 0.3 | 4 |
| 80/03/26 | 1.8 | 11 | 6.80 | 15.2 | 116.4 | 0.3 | 4 |
| 80/05/14 | 5.6 | -- | 6.60 | -- | -- | 0.5 | 1 |
| 80/06/20 | 9.0 | 10 | 6.45 | 11.9 | 108.7 | 0.4 | 1 |
| 12141880 | | | | | | | |
| 47 39 15.0 121 39 22.0 4 Station 2 | | | | | | | |
| Sunday Cr. above mouth at County Road Bridge | | | | | | | |
| 79/07/20 | 16.6 | 12 | 6.10 | 9.1 | 98.0 | -- | -- |
| 79/07/24 | 14.6 | 14 | -- | 9.5 | 98.0 | -- | -- |
| 79/08/21 | 14.9 | 15 | -- | 10.6 | 110.4 | -- | 6 |
| 79/09/18 | 13.7 | 28 | -- | 10.2 | 103.5 | 0.1 | 6 |
| 79/10/16 | 10.8 | 20 | -- | 10.1 | 95.5 | 0.2 | 6 |
| 79/11/14 | 6.2 | 15 | -- | 12.4 | 105.2 | 0.2 | 4 |
| 80/02/22 | 3.7 | 11 | 6.60 | 13.8 | 110.4 | 0.3 | 4 |
| 80/03/26 | 3.3 | 10 | 6.70 | 14.2 | 112.8 | 0.7 | 4 |
| 80/05/14 | 7.2 | -- | 6.60 | -- | -- | 0.5 | 1 |
| 80/06/20 | 11.0 | 16 | 6.40 | 11.2 | 106.8 | 0.6 | 4 |

Table 1. Water quality data from the COE North Fork Snoqualmie River sampling program - continued.

| Date | Water temp. Cent. | Conductivity at 25°C micromho | pH | DO MG/L | DO satur. percent | Turbidity trbidmtr hach FTU | Phenolphthalein alk MG/L |
|---|---|---|---|---|---|---|---|
| 12141915 | | | | | | | |
| 47 39 29.0 121 40 44.0 4 Station 1 | | | | | | | |
| N. Fk Snoqualmie at Wagner Bridge near Snoqualmie Falls | | | | | | | |
| 79/07/20 | 18.4 | 22 | 6.55 | 9.0 | 101.0 | -- | -- |
| 79/07/24 | 15.1 | 22 | -- | 9.5 | 98.6 | -- | -- |
| 79/08/21 | 15.6 | 34 | -- | 10.8 | 113.4 | -- | 13 |
| 79/09/18 | 14.5 | 36 | -- | 10.1 | 103.9 | 0.3 | 17 |
| 79/10/16 | 10.5 | 40 | -- | 10.6 | 98.9 | 0.7 | 18 |
| 79/11/14 | 5.9 | 44 | -- | 11.8 | 99.0 | 2.6 | 13 |
| 80/02/22 | 4.0 | 20 | -- | 14.2 | 113.7 | 1.4 | 10 |
| 80/03/26 | 3.7 | 20 | 7.20 | 14.4 | 114.9 | 1.9 | 16 |
| 80/05/14 | 6.7 | -- | 6.90 | -- | -- | 3.0 | 8 |
| 80/06/20 | 13.5 | 34 | 6.85 | 11.2 | 109.9 | 1.4 | 18 |
| Beaver Pond | | | | | | | |
| 79/07/20 | 16.0 | 54 | -- | 8.1 | -- | -- | -- |

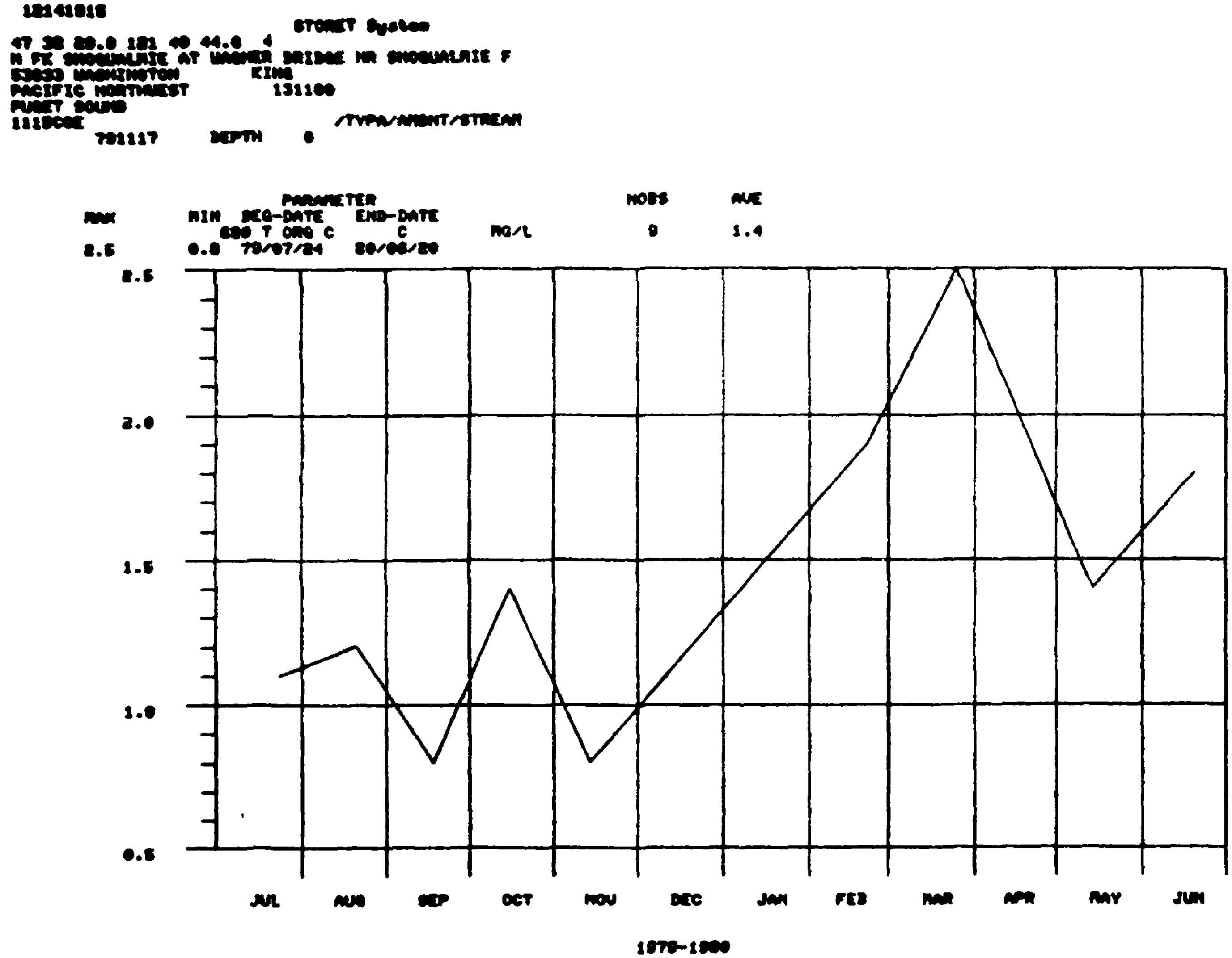



Figure 30. North Fork Snoqualmie River total organic carbon at Wagner Bridge from the COE water quality sampling program.

Total Kjeldahl nitrogen was recorded as 1.15 mg/l on 24 July 1979. We reported this unusually high nutrient reading in our 1980 report, but COE has now informed us that this figure was in error. All subsequent measurements were considerably lower. Concentrations of nutrients such as nitrates and phosphates were very low (U.S. Army Corps of Engineers, 1980a).

Water quality in the North Fork Snoqualmie River basin is presently good. If anything, alkalinity and nutrient values are quite low in the upper river and may possibly be limiting aquatic production.

## Aquatic Macrophytes

Macrophytes can act as cover for juvenile and adult fish and as food for aquatic insects. They are important for their contribution to the productivity of aquatic systems.

Only two macrophytes were observed growing in the river. Fennel-leaved potamogeton (*Potamogeton pectinatus*) was found growing in silt accumulations on rocks in slow water near RM 18.2. An unidentified horsetail (*Equisetum* sp.) carpeted the clay-silt river bottom near RM 17.3. It also grew high above the water line. This genus has been observed growing in Wyoming brown trout streams (Binns 1972).

Table 2 is a list of aquatic macrophytes collected from two beaver ponds and two oxbow sloughs including Fitchener Slough. Of particular interest is the carnivorous bladderwort. This common plant has the unusual habit of feeding on zooplankton.

## Benthos

In addition to their importance as fish food, benthic macroinvertebrates are indicators of water quality and relative productivity in aquatic environments. We were limited to processing only the June 1979, river benthic sample. Numbers of insects per $m^2$ ranged from 272 to 1,600 with mayflies (Ephemeroptera) comprising between 46.8 percent and 82.7 percent (Table 3). Sample site number 1 had over 1,272 mayflies per $m^2$. The percentage of aquatic fly larvae (Diptera) ranged from 1.6 percent to 25.3 percent. At station number 4, over 377 Diptera per $m^2$ were recorded.

The most abundant insect found in the river was the heptageneiid mayfly of the genus *Cinygmula*. It comprised over 28 percent of our sample (Table 4). According to Edmunds et al. (1976), *Cinygmula* is one of the most common mayflies in the western mountains. The nymphs live under stones in most parts of many streams. The nymphs can move fairly rapidly across stones but are very poor swimmers. They are commonly found drifting in streams and are frequently preyed upon by trout.

Table 2. Aquatic macrophytes collected in beaver ponds and oxbow sloughs, North Fork Snoqualmie basin.

| | |
|---|---|
| *Juncus effusus* | common rush |
| *Juncus oxymeris* | pointed rush |
| *Lysichitum americanum* | skunk cabbage |
| *Myriophyllum spicatum* | water milfoil |
| *Nuphar polysepalum* | yellow pond lily |
| *Oenanthe sarmentosa* | water parsley |
| *Potamogeton natans* | broad-leafed pond weed |
| *Rorippa nasturtium-aquaticum* | water cress |
| *Sparganium emersum* | bur-reed |
| *Typha latifolia* | common cattail |
| *Utricularia vulgaris* | bladderwort |
| *Vallisneria americana* | tapegrass |

Table 3. **Abundance of aquatic invertebrates collected in North Fork Snoqualmie River, June 1979.**

| | Sampling station | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | |
| | #/$m^2$ | % | #/$m^2$ | % | #/$m^2$ | % | #/$m^2$ | % | #/$m^2$ | % | #/$m^2$ | % | #/$m^2$ | % |
| Ephemeroptera | 1272.5 | 80.3 | 483.4 | 51.8 | 161.1 | 46.8 | 966.7 | 60.[illegible] | 188.9 | 69.3 | 533.4 | 82.7 | 527.8 | 61.6 |
| Plecoptera | 161.2 | 10.2 | 194.5 | 20.8 | 127.8 | 37.1 | 177.7 | 11.1 | 44.4 | 16.3 | 44.5 | 6.9 | 44.4 | 5.2 |
| Trichoptera | 28.0 | 1.7 | 5.6 | .6 | 5.6 | 1.6 | 38.9 | 2.4 | 5.6 | 2.1 | - | - | 16.8 | 1.9 |
| Diptera | 66.7 | 4.2 | 244.6 | 26.2 | 5.6 | 1.6 | 377.9 | 23.7 | 27.8 | 10.2 | 50.1 | 7.8 | 216.7 | 25.3 |
| Coleoptera | 5.6 | .4 | - | - | - | - | 38.9 | 2.4 | 5.6 | 2.1 | 5.6 | .9 | 16.7 | 2.0 |
| Collembola | 5.6 | .4 | - | - | - | - | - | - | - | - | - | - | - | - |
| Oligochaeta | - | - | - | - | 27.8 | 8.1 | - | - | - | - | - | - | 16.7 | 2.0 |
| Unknown | 44.4 | 2.8 | 5.6 | .6 | 16.7 | 4.8 | - | - | - | - | 11.1 | 1.7 | 16.7 | 2.0 |
| TOTAL | 1584.0 | 100 | 933.7 | 100 | 344.6 | 100 | 1600.1 | 100 | 272.3 | 100 | 644.7 | 100 | 855.8 | 100 |

Table 4. Relative abundance of aquatic invertebrates collected by Mundie sampler in North Fork Snoqualmie River, June 1979.

| | Average number/sample | Percent of total |
|---|---|---|
| INSECTA | | |
| Ephemeroptera | | |
| *Cinygmula* sp. | 45.57 | 28.43 |
| *Epeorus* sp. | 20.28 | 12.66 |
| *Baetis* sp. | 24.43 | 15.24 |
| *Ephemerella* sp. | 10.43 | 6.51 |
| *Ameletus* sp. | 2.43 | 1.51 |
| *Paraleptophlebia* sp. | 1.71 | 1.07 |
| UNID. Ephemeroptera | 1.14 | 0.71 |
| *Rhithrogena* sp. | 0.29 | 0.18 |
| Plecoptera | | |
| UNID. Chloroperlidae | 6.86 | 4.28 |
| *Alloperla* sp. | 12.71 | 7.93 |
| *Acroneuria* sp. | 0.29 | 0.18 |
| UNID. Plecoptera | 0.57 | 0.36 |
| Trichoptera | | |
| UNID. Trichoptera | 1.00 | 0.62 |
| *Glossosoma* sp. | 0.29 | 0.18 |
| *Hydropsyche* sp. | 0.14 | 0.09 |
| *Brachycentrus* sp. | 0.43 | 0.27 |
| *Rhyacophila* sp. | 0.29 | 0.18 |
| *Himalopsyche* sp. | 0.14 | 0.09 |
| UNID. Odontoceridae | 0.14 | 0.09 |
| UNID. Hydropsychidae | 0.14 | 0.09 |
| Diptera | | |
| UNID. Chironomidae | 16.28 | 10.16 |
| *Antocha* sp. | 3.71 | 2.31 |
| *Atherix variegata* | 1.71 | 1.07 |
| UNID. Diptera | 1.71 | 1.07 |
| *Hexatoma* sp. | 1.14 | 0.71 |
| *Palpolyia*/*Bezzia*/*Probezzia* sp. | 0.29 | 0.18 |
| *Tipula* sp. | 0.14 | 0.09 |
| *Hesperoconopa* sp. | 0.14 | 0.09 |
| *Simulium* sp. | 0.14 | 0.09 |
| UNID. Tipulidae (pupa) | 0.14 | 0.09 |
| Coleoptera | | |
| *Narpus* sp. | 1.57 | 0.98 |
| UNID. Carabidae | 0.14 | 0.09 |
| UNID. Coleoptera | 0.14 | 0.09 |
| Collembola | | |
| UNID. Sminthuridae | 0.14 | 0.09 |
| OLIGOCHAETA | 1.14 | 0.71 |
| UNID. | 2.43 | 1.51 |
| | | 100.00 |

Due to our limited river sampling, it was not practical to assign any significance to the differences in numbers from station to station. However, the overall water quality of the North Fork Snoqualmie River appears to be excellent. We have identified 28 taxonomic groups. While most of these are known to genus, several have been identified only to family. Cairns and Dickson (1971) stated that a large benthic species diversity in a stream usually represents a stable, unstressed system.

The Chironomidae, or midge family, constitute about 10 percent of the total stream organisms collected. There were about 90 chironomids/$m^2$. In some rivers polluted by organic wastes their numbers may be as high as 50,000/$m^2$ (Coffman 1978). Two other relatively unpolluted rivers in western Washington, the Sauk and Cascade, (Skagit River basin) had between 12 percent 37 percent chironomids and 4 percent and 26 percent chironomids respectively, depending on the time of year (Gislason 1980).

The density of benthos was greater in the beaver ponds than in the river. We recorded over 2,325 organisms per $m^2$ of bottom (Table 5). Chironomids comprised almost 65 percent of this total with 1,509 per $m^2$.

We reported results of stomach content analysis on river and pond trout in our 1980 report (pp. 60-63).

## Fish

### River and Streams

We captured four species of fish while electro-fishing at seven river block net stations. These were cutthroat trout, rainbow trout, brook trout, and shorthead sculpin (*Cottus confusus*). Populations of sculpins were not estimated during river block netting, but sculpin numbers were recorded during spot electroshocking.

Salmonid species composition varied at different stations (Table 6). Cutthroat trout were most abundant at the upstream stations while rainbow trout were most abundant at the lower and middle stations. Rainbow trout were the most abundant species below the mouth of Sunday Creek at RM 16.4. Brook trout achieved their maximum abundance, 11 to 15 percent between RM 14.6 and 18.2 (stations 3 and 4).

The greatest number of fish/mile was at station 6, Wagner Campground. This area was described in our 1980 report (p. 31) as being quite heterogeneous with regard to its substrate and current velocity. It was heavily used by rainbow trout of all sizes. The next greatest densities of trout were found near Spur 10 bridge (station 7) and in the extreme upper river (station 1).

AD-A111 745 WASHINGTON STATE DEPT OF GAME OLYMPIA F/G 6/3
NORTH FORK SNOQUALMIE RIVER BASIN WILDLIFE STUDY.(U)
MAR 81 S J SWEENEY, K W KURKO, T C JUELSON DACW67-79-C-0050

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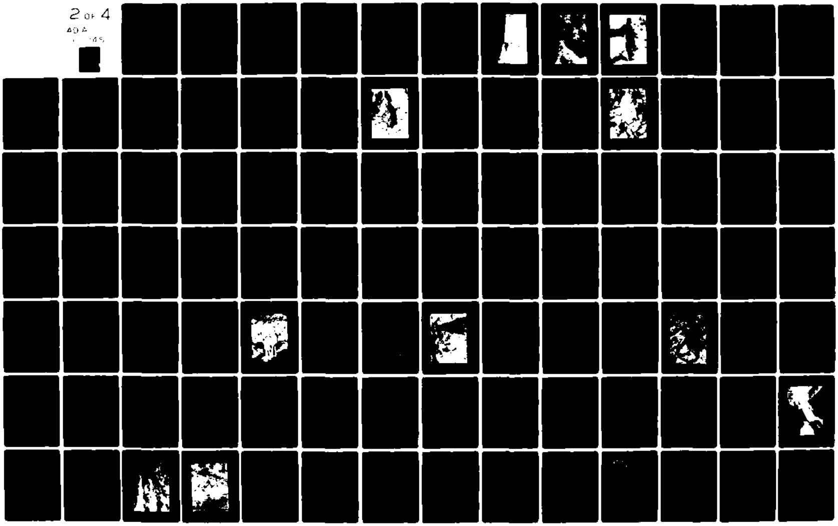
AD A



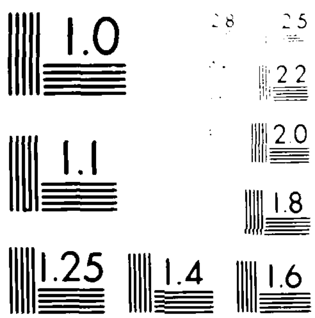

1.0
2.5
2.2
1.1
2.0
1.8
1.25
1.4
1.6

Table 5. Abundance of benthic invertebrates collected by Ponar grab from two beaver ponds in the North Fork Snoqualmie basin.

| | Number collected | Number/$m^2$ | Average number/sample | Percent of total |
|---|---|---|---|---|
| Arthropoda | | | | |
| Insecta | | | | |
| Trichoptera | | | | |
| *Psychoglypha* sp. | 1 | 43.1 | 0.5 | 1.8 |
| Diptera | | | | |
| Chironomidae | 35 | 1506.9 | 17.5 | 64.9 |
| Odonata | 1 | 43.1 | 0.5 | 1.8 |
| Annelida | | | | |
| Oligochaeta | 16 | 688.9 | 8.0 | 29.7 |
| Mollusca | | | | |
| Pelecypoda | | | | |
| Sphaeridae | 1 | 43.1 | 0.5 | 1.8 |
| TOTAL | 54 | 2325.1 | 27.0 | 100.0 |

Table 6. Summary of river blocknetting in North Fork Snoqualmie River.

| Block net station | Fish/mile | Fish/$m^2$ | g/$m^2$ | Mean length (mm) | Length range (mm) | Mean weight (g) | Weight range (g) | Species composition |
|---|---|---|---|---|---|---|---|---|
| 1 | 2050±100 | .20±.010 | 2.17±.11 | 88 | 41-207 | 11.0 | <1-54 | 99% cutthroat trout<br>1% brook trout |
| 2 | 1811±325 | .09±.016 | 0.40±.07 | 66 | 37-129 | 4.5 | <1-21 | 85% cutthroat trout<br>15% brook trout |
| 3 | 923±538 | .02±.014 | 0.28±.16 | 82 | 48-190 | 12.1 | 1-82 | 67% rainbow trout<br>22% cutthroat trout<br>11% brook trout |
| 4 | 567±6 | .01±.000 | 0.20±.00 | 93 | 46-173 | 16.0 | 1-68 | 65% rainbow trout<br>23% cutthroat trout<br>12% brook trout |
| 5 | 1900±100 | .05±.003 | 1.29±.07 | 116 | 40-244 | 25.7 | <1-157 | 91% rainbow trout<br>9% cutthroat trout |
| 6 | 4774±1355 | .09±.026 | 1.51±.43 | 86 | 34-204 | 16.4 | <1-89 | 99% rainbow trout<br>1% brook trout |
| 7 | 2708±84 | .05±.002 | 0.84±.04 | 83 | 39-271 | 15.9 | <1-260 | 100% rainbow trout |

Station 1 also contained the largest number of fish/$m^2$ (0.20) and the greatest biomass (2.17 g/$m^2$). It was heavily populated with sub-legal cutthroat trout (<6 in). This station appears to be an excellent juvenile rearing area which could provide recruitment to the river downstream.

The next three stations with the greatest biomass were 6, 5, and 7, with 1.51, 1.29, and 0.84 g/$m^2$, respectively. Bisson and Sedell (in preparation) state that salmonid biomasses below 2 g/$m^2$ are typical of forested streams in the coastal and western Cascades of Washington and Oregon. Chapman and Knudsen (1980) recorded biomasses of cutthroat and steelhead trout in numerous small streams of Puget Sound basin. During June and July they averaged 1.95 g/$m^2$, while during August and September they averaged 2.60 g/$m^2$. Many of these streams also contained coho salmon, and thus the total stream biomass was even greater than that reported here. In the Cedar River, Casne (1975) found biomasses consisting of rainbow, cutthroat, and Dolly Varden trout generally ranging from 0.59 g/$m^2$ to 3.74 g/$m^2$ with one record as high as 5.99 g/$m^2$.

Five of the seven block net stations were upstream of the proposed North Fork damsite. Station 6 was 0.7 mile below the damsite, but we believe that this station best represents the river habitat from the damsite upstream to about RM 13.3. The COE notified us in May 1980, that the proposed reservoir's high pool elevation would be 1,532 ft rather than 1,545 ft as given in our 1980 report. This lower pool elevation would then inundate about 8.8 mi of river instead of 9.0 mi as previously reported. The mean number of trout per mile in stations 1 to 6 was 2,105 $\pm$ 358. This figure when multiplied by the estimated 8.8 miles of river that would be inundated, gave a population estimate of 18,524 $\pm$ 3,150 trout. This was the population estimate for the section of river that would be flooded by the proposed North Fork Snoqualmie dam. This figure did not include an estimate of the tributary fish populations in the zone of inundation. No population estimate was made for the river below the proposed dam because of the comparative lack of representative block net stations for this section's relative length.

We felt that these block netting data were somewhat biased against large fish. We could not effectively electroshock deep pools which tend to contain larger trout. River snorkel surveys were started partly to overcome this bias and partly for their efficiency in covering areas of river quickly. On the other hand, snorkel surveys ten[illegible] biased against trout under 3 in. long, simply because these trout o[illegible]n inhabit very shallow water in which divers cannot swim.

The reaction of trout to a slowly swimming diver is surprisingly slight. A diver can approach to within 2 ft of a trout before it becomes alarmed. We hand fed eager schools of 20 to 30 trout by picking aquatic insects off rocks and letting them drift with the current 2 or 3 ft. On several occasions we saw fish marked with our small Floy tags but could not read the numbers.

The greatest number of fish seen was between RM 12.2 and 13.3 above Wagner bridge (Table 7). Nearby, block net station 6 (RM 11.8) also had the highest number of fish per mile. In addition, RM 12.2 to 13.3 contained the largest number and percentage of sub-legal (less than 6 in.) fish per mile seen anywhere in the river. This confirmed our impression that this section is an important juvenile rearing area.

The next two river sections with the greatest number of fish per mile were RM 0.3 to 1.8 and RM 3.3 to 4.5. These two sections are below Ernie's Grove, and part of Black Canyon, (Fig. 3, p.14). The number of fish reported in Black Canyon was a conservative figure. Substantial sections of the canyon were not snorkeled because of danger. Thus the figure 381 fish/mile would otherwise be higher. RM 0.3 to 1.8 are below the 3.0 to 4.6-m (10 to 15-ft) waterfall near RM 3.1. This section of river contains several species not found farther upstream. These are mountain whitefish, largescale sucker, longnose dace, and mottled sculpin. We saw more whitefish than any other species. The largescale suckers were in two schools. One contained 3 fish while the other contained 80 fish. These suckers averaged 450 to 600 mm (17 to 24 in.) and the larger school was very impressive.

While turning over rocks, we noticed a great number of large benthic invertebrates. Chief among these was a stonefly of the genus Pteronarcys. The abundant insect fauna is one of the reasons this section of river supported a combined population of rainbow trout and mountain whitefish that contained twice as many fish per mile than any other river section snorkeled.

These two lowest river reaches snorkeled contained the greatest densities of legal (6 in. or longer) trout and trout over 9 in. long (Tables 7 and 8). They are also the river sections (Photo 22) that would be most affected by the proposed reregulating reservoir and downstream power canal. Another river section with a high number of large fish was the section between RM 9.2 and 10.1. This reach is just above the USGS gage and is near and similar to the river section that would be inundated by the proposed reregulating reservoir. It is characterized by short, fast rapids, and numerous large pools (Photo 23). The largest trout seen in the North Fork Snoqualmie River was here in a large pool. We estimated its length to be 20 in. Several 16 to 18-in. trout were also observed (Photo 24).

The largest number of 0 to 3-in. fish seen per mile was 79 (Table 8). This occurred between RM 18.2 and 19.1 near Phelps Campground. In our electroshocking work in this same area, block net station 2 also contained many juvenile trout. This river section appears to have excellent spawning habitat and the large number of small fish seen here may be partly a result.

Our 1980 report presented detailed results of spot electroshocking surveys conducted on the North Fork Snoqualmie River in 1979 (pp. 73 and

Table 7. Total number of fish, number of legal-size fish, and number of sub-legal fish observed during snorkel surveys of North Fork Snoqualmie River.

| River miles | Species | Total # of fish /mile | Legals /mile | Percent of total | Sub-legals /mile | Percent of total |
|---|---|---|---|---|---|---|
| 19.1 - 20.0 (0.9 miles) | cutthroat, brook | 160 | --- | --- | --- | --- |
| 18.2 - 19.1 (0.9 miles) | cutthroat, brook | 298 | 93 | 31 | 204 | 69 |
| 17.3 - 18.2 (0.9 miles) | cutthroat, rainbow, brook | 230 | 76 | 33 | 154 | 67 |
| 16.4 - 17.3 (0.9 miles) | cutthroat, rainbow, brook | 77 | 7 | 9 | 70 | 91 |
| 15.6 - 16.4 (0.8 miles) | cutthroat, rainbow, brook | 149 | 45 | 30 | 104 | 70 |
| 14.6 - 15.6 (1.0 miles) | cutthroat, rainbow, brook | 183 | 68 | 37 | 115 | 63 |
| 13.7 - 14.6 (0.9 miles) | cutthroat, rainbow, brook | 186 | 74 | 40 | 111 | 60 |
| 13.3 - 13.7 (0.4 miles) | cutthroat, rainbow, brook | 163 | 60 | 37 | 103 | 63 |
| 12.2 - 13.3 (1.1 miles) | rainbow, brook | 716 | 175 | 24 | 541 | 76 |
| 9.2 - 10.1 (0.9 miles) | rainbow | 139 | 83 | 64 | 47 | 36 |
| 3.3 - 4.5 (1.2 miles) | rainbow | 358 | 242 | 67 | 117 | 33 |
| 0.3 - 1.8 (1.5 miles) | rainbow,<br>whitefish | 381<br>407 | 247<br>186 | 65<br>46 | 134<br>221 | 35<br>54 |

Table 8. Number of 0-3 inch fish per mile and number of fish over 9 inches per mile, observed during snorkel surveys of North Fork Snoqualmie River.

| River miles | Species | Number of 0-3 inch fish/mile | Percent of total | Number of >9 inch fish/mile | Percent of total |
|---|---|---|---|---|---|
| 19.1 - 20.0 (0.9 miles) | cutthroat, brook | --- | --- | --- | --- |
| 18.2 - 19.1 (0.9 miles) | cutthroat, brook | 79 | 26 | 13 | 4 |
| 17.3 - 18.2 (0.9 miles) | cutthroat, rainbow, brook | 30 | 13 | 13 | 6 |
| 16.4 - 17.3 (0.9 miles) | cutthroat, rainbow brook | 6 | 7 | 6 | 7 |
| 15.6 - 16.4 (0.8 miles) | cutthroat, rainbow, brook | 15 | 10 | 2 | 2 |
| 14.6 - 15.6 (1.0 miles) | cutthroat, rainbow, brook | 13 | 7 | 9 | 5 |
| 13.7 - 14.6 (0.9 miles) | cutthroat, rainbow, brook | 17 | 9 | 4 | 2 |
| 13.3 - 13.7 (0.4 miles) | cutthroat, rainbow, brook | 8 | 5 | 8 | 5 |
| 12.2 - 13.3 (1.1 miles) | rainbow, brook | 54 | 7 | 25 | 3 |
| 9.2 - 10.1 (0.9 miles) | rainbow | 23 | 18 | 42 | 32 |
| 3.3 - 4.5 (1.2 miles) | rainbow | 33 | 9 | 81 | 23 |
| 0.3 - 1.8 (1.5 miles) | rainbow, | 31 | 8 | 89 | 23 |
| | whitefish | 65 | 16 | 25 | 6 |

Photo 22. North Fork Snoqualmie River looking downstream from the site of the reregulating dam near RM 5.9. The beginning of the Black Canyon can be seen in the distance.

Photo 23. North Fork Snoqualmie River looking downstream near the site of the USGS gage at RM 9.2. This river section contained some of the largest trout seen during our study.

Photo 24. A 381-mm (15-in) rainbow trout caught near RM 9.2.

74). These data reinforced the species distribution patterns observed in the block netting and snorkeling studies. We caught an average of 4.2 shorthead sculpins for every trout. A crude estimate of the sculpin population above the proposed damsite can be obtained by multiplying the estimated number of trout in the proposed reservoir site by 4.2. This gives an estimate of 77,801 $\pm$ 13,230 sculpins in the approximately 8.8 miles of river that would be flooded (does not include tributaries).

Comparisons with other rivers are difficult because sculpin populations have not usually been estimated in the past. However their great abundance must have a significant effect on river ecology. Shorthead sculpins probably compete with smaller trout for some prey items, but also serve as prey items themselves for larger trout. Several were found in trout stomachs. Sculpins are known to prey upon trout eggs, but this could function to limit intraspecific competition among juvenile trout and actually increase their growth rates.

During our spot electroshocking, sculpin specimens captured in the extreme lower river near Ernie's Grove were misidentified as torrent sculpins (Cottus rhotheus). Professor Carl Bond, Professor of Fisheries at Oregon State University, identified them as mottled sculpins (Cottus bairdi). These were the first records of this common sculpin above Snoqualmie Falls.

During the 1980 field season, we electroshocked the five major tributaries of the proposed North Fork Snoqualmie reservoir (Fig.11, p. 30 ). This was to investigate present use of these tributaries by resident fish.

Salmonid species composition was dominated by cutthroat trout in all streams except Philippa Creek (Table 9). In the latter, rainbow trout comprised 52 percent of fish captured. This may be related to recent rainbow trout fry plants by WDG in Philippa Lake. This alpine lake is 4.8 km (3.0 mi) from the mouth of Philippa Creek and lies at an elevation of 1,020.8 m (3,346 ft). Some or all of the rainbow trout captured in the creek may have originated from the stock in Philippa Lake. This seems especially likely since no rainbow trout were shocked in Sunday Creek, and its major tributary is Philippa Creek.

We captured the greatest number of salmonids per hour in the upper North Fork Snoqualmie River (Table 9). This upper section of river is characterized by boulder-filled rapids, interspersed regularly with pools. Instream brush piles and log jams are frequent. These boulders and brush piles provide excellent juvenile trout rearing habitat.

Sunday, Philippa, and Lennox Creeks contained the lowest salmonid densities. Sunday and Phillipa Creeks have larger pools than the upper North Fork. These provide less habitat for juvenile trout and reduced overall salmonid densities. Lennox Creek contained the lowest salmonid

Table 9. Salmonid species composition, salmonids per hour, and shorthead sculpins per hour in tributary streams of the proposed North Fork Snoqualmie reservoir. Data are from 1980 electroshocking surveys.

| Stream | River miles | Salmonid species composition | Salmonids/hr | Shorthead sculpins/hr |
|---|---|---|---|---|
| GF | 0.0 - 0.6 | 98% cutthroat<br>2% brook | 14.8 | 7.9 |
| Sunday | 0.1 - 1.4 | 100% cutthroat | 11.5 | 14.8 |
| Philippa | 0.0 - 0.9 | 52% rainbow<br>44% cutthroat<br>4% brook | 8.2 | 10.0 |
| Lennox | 0.0 - 1.1 | 100% cutthroat | 4.1 | 6.6 |
| Upper N. Fork | 21.2 - 22.0 | 100% cutthroat | 20.0 | 7.3 |

and shorthead sculpin densities of any tributary of the proposed reservoir. The lower reach of Lennox Creek provides poor fish habitat. Few pools, little instream cover, and lack of overhanging riparian vegetation, are some of the prime causes. Habitat quality improves upstream, but the number of fish electroshocked was still low. Lennox Creek conductivities were usually the lowest of those recorded at all four COE water quality stations (Table 1, page 70). Low dissolved mineral or nutrient concentrations may be a factor contributing to the apparent low productivity.

Philippa Creek contained the largest trout of the five tributary streams we surveyed (Table 10). Their mean fork length averaged 126.7 mm (5.0 in). Sunday Creek trout were the smallest and averaged only 8.01 mm (3.2 in). Lower Sunday Creek contains fairly good adult trout habitat. There are frequent large pools with big stumps for cover. These large pools were difficult to shock because of their depth and water clarity. On another occasion, we hooked larger trout in several of these pools with a rod and reel. The smaller than average size of trout from Sunday Creek may be due to the difficulty in shocking its many deep pools. In contrast, Philippa Creek had few pools that were not wadeable.

The largest sculpins were captured in the upper North Fork Snoqualmie River (Table 11). Their mean length was 82.5 mm (3.2 in). Wydoski and Whitney (1979) reported that shorthead sculpins are generally found at higher altitudes than most other sculpins. They prefer a rubble or gravel bottom and cool water temperatures less than 15.6°C (60°F).

The notable differences between the upper North Fork and the other streams we surveyed were: 1) the preponderance of old growth forest along its banks, and 2) the high density of juvenile salmonids (Table 9). Possibly the factors that make the upper North Fork good juvenile trout habitat also make it good shorthead sculpin habitat (Table 11). Or sculpins could be feeding on trout eggs or small trout, when available to them.

No sculpins were captured from GF Creek above the 3-ft fall and braided channel area located about half way between the river and Spur 30 (Fig. 16, p. 44). The part of GF Creek above this areas has a steep mountainous character with numerous boulders, rapids, small falls, and a few pools. We do not know why sculpins were not found in this section. Cutthroat trout were not common but were present in the pools. Interestingly, in this steep upper section, cutthroat trout ranged in length from 119 to 200 mm (4.7 to 7.9 in). Whereas trout in the lower creek ranged from 37 to 204 mm (1.5 to 8.0 in). Small cutthroat trout, while present in lower GF Creek, were not found in the steep upper section. This was opposite the general size distribution pattern we observed during snorkel surveys for trout in the main river. As the river increased in size downstream and pools became larger, bigger trout became more common (Table 8, p. 83). Bisson and Sedell (in preparation) note that larger

Table 10. Size of salmonids in tributary streams of the proposed North Fork Snoqualmie reservoir from 1980 electroshocking surveys.

| Stream | Salmonid mean length (mm) | Salmonid length range (mm) | Salmonid mean weight (g) | Salmonid weight range (g) |
|---|---|---|---|---|
| GF | 113.4 | 37-204 | 23.7 | <1-83 |
| Sunday | 80.1 | 44-176 | 8.3 | <1-61 |
| Philippa | 126.7 | 42-248 | 30.5 | 1-169 |
| Lennox | 113.8 | 55-171 | 21.3 | 2-53 |
| Upper N. Fork | 105.1 | 36-164 | 16.2 | <1-49 |

Table 11. Length of shorthead sculpins in tributary streams of the proposed North Fork Snoqualmie reservoir from 1980 electroshocking surveys.

| Stream | Sculpin mean length (mm) | Sculpin length range (mm) |
|---|---|---|
| GF | 64.1 | 24-107 |
| Sunday | 56.4 | 35-85 |
| Philippa | 62.5 | 22-85 |
| Lennox | 66.9 | 29-95 |
| Upper N. Fork | 82.5 | 52-120 |

trout prefer high quality pools (large, deep, and with abundant cover). Lower GF Creek combines high quality pools with some good juvenile rearing habitat (shallow areas with abundant instream cover). Upper GF Creek contains some high quality pools but little juvenile rearing area. This probably explains the lack of cutthroat trout under 119 mm (4.7 in) during our electroshocking survey in upper GF Creek.

We analyzed scales collected from some river and tributary stream fish (Table 12). To minimize variation we examined scales obtained only from fish during September and October. Because of small sample size, scale analysis results were combined for cutthroat and rainbow trout in both the river and tributary streams. No scales were collected from trout less than 80-mm (3.1-in) long. At this length, fish were all age 1+. Therefore we were not able to differentiate the lower length range of age 1+ fingerlings from the upper length range of age 0+ fry (Table 12).

We captured one age 4+ rainbow trout which was 375 mm (14.8 in) long in October. This was a female with eggs and would probably have spawned the following spring. Examination of her scales indicated that she had spawned at age 2+. This suggests a pattern of spawning every other year, which is often characteristic of higher elevation trout populations. Age and growth of North Fork Snoqualmie River and tributary stream fish is slower than trout growth in lowland streams. However, growth is probably within the typical range for western Washington streams at similar elevations (pers. commun., Ted Muller, WDG, Seattle, Wash.). When compared to other areas in the Northwest (Table 13), growth in the North Fork Snoqualmie seems about average (Wydoski and Whitney 1979).

One mountain whitefish scale sample was collected from the river below Ernie's Grove during our creel census. This specimen was 347 mm (13.7 in) long and was age 6+. It was probably one of the older individuals since we saw few whitefish larger than this during the snorkel survey of the area.

Details of hatchery fish stocking by WDG and WDF were presented in our 1980 report (pp. 73 to 76). The most recent WDG plants were in 1975 and consisted of eyed, cutthroat eggs placed in the upper river and Sunday Creek. In 1974 an unidentified beaver pond and Fitchener Slough were planted with cutthroat fry. It is unlikely that many fish remain from these hatchery plants made over 6 years ago. Almost all fish now in the system are from natural reproduction.

Between 1977 and 1979 the Department of Fisheries made four plants of coho salmon fry in the lower North Fork Snoqualmie. We never observed salmon in any part of the North Fork. These plants and their ecological implications were discussed in detail in our 1980 report (pp. 75 and 76).

Table 12. Age and length of trout from the North Fork Snoqualmie River and tributary streams.

| Age | Mean fork length (mm) | Length range (mm) |
|---|---|---|
| 0+ | ? | 34-? |
| 1+ | 142(?) | 80(?)-204 |
| 2+ | 242 | 211-273 |
| 3+ | 305 | 284-325 |
| 4+ | 375 | 375* |

*only one fish in sample.

Table 13. Age and length of rainbow and cutthroat trout in the Northwest.

| Species | Location | Total length(mm) at age 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| rainbow | Ross Lake tributaries, Wash. | 127 | 163 | 188 | 198 |
| | Ross Lake, Wash. | 122 | 267 | 345 | 384 |
| | Chester Morse Lake, Wash. | 99 | 191 | 307 | 399 |
| | Pyramid Lake, Alberta | 61 | 135 | 191 | 236 |
| cutthroat | Priest Lake tributaries, Idaho | 86 | 127 | 170 | 201 |
| | Priest Lake, Idaho | 81 | 135 | 211 | 287 |
| | Sand Creek, Oregon (sea-run) | 69 | 112 | 323 | 376 |
| | Yellowstone Lake, Wyoming | 46 | 130 | 224 | 312 |

In the summer of 1979, we marked about 150 rainbow and cutthroat trout with small, numbered Floy tags. We saw several tagged fish during snorkel surveys the same summer, but were unable to approach closely enough to read the tiny lettering.

In October 1979, a fisherman reported catching a tagged fish at Wagner bridge. However, he had already eaten the fish and forgotten the tag's number. Two marked rainbow trout were caught by anglers in 1980. One fish was tagged at Wagner Campground and was caught near the mouth of Deep Creek, one mile downstream. The other rainbow was tagged at the mouth of Sunday Creek and was recovered 13 miles downstream in Black Canyon. As measured by the fisherman, the first fish had grown about 64 mm (2.5 in) in ten months, and the latter had grown about 89 mm (3.5 in) in the same period.

With only 2 tags returned it is difficult to say anything definite about river trout movements. However, during snorkel surveys, the number of larger trout generally increased downstream. Both our tagged fish were recaptured farther downriver. Some trout in the river and tributary streams may be moving downstream into better adult habitat as they grow larger.

Ponds

In 1979, population estimates were made for two beaver ponds that we intensively sampled with a fyke net and minnow traps. Details were presented in our 1980 report (pp. 76 to 80). For a beaver pond in pond system 17 (Fig. 12, p.32 and Photo 25), we estimated a population of 62 trout. The 95 percent asymmetrical confidence limits were 47 and 84 fish (Table 14). A projected 76 percent of these fish were cutthroat trout and 24 percent were brook trout. We estimated trout biomass to be 2.74 $g/m^2$ of surface area.

For a beaver pond in pond system 24 (Fig. 12, p. 32 ), we estimated a population of 286 trout. The 95 percent asymmetrical confidence limits were 206 and 410 fish (Table 15). A projected 97 percent of these fish were cutthroat trout and 3 percent were brook trout. We estimated trout biomass to be 9.69 $g/m^2$ of surface area.

Both ponds had more fish biomass per $m^2$ of surface area than any river block net station. The single conductivity measured in a beaver pond was about 2.5 times greater than the highest value measured in the river on the same day (Table 1, p. 70 ). This was probably one of the reasons that benthic macroinvertebrate densities were higher in beaver ponds than in the river (Table 3, p. 75 and Table 5, p. 78 ).

A 3-year study of the effects of beaver on trout was conducted in the Sierra Nevada Mountains of California by Gard (1961). After beavers built a dam on a stream the following physical changes occurred: the substrate changed from gravel and cobble to silt, water velocities

Photo 25. Beaver pond in pond system 17 which was intensively sampled with a fyke net and minnow traps.

Table 14. Population estimates and size of trout from a beaver pond in pond system 17, North Fork Snoqualmie basin.

| | $\hat{N}$ | $\hat{N}$ 95% confidence limits | Biomass (g) | Biomass 95% confidence limits (g) | Mean length (mm) | Length range (mm) | Mean weight (g) | Weight range (g) |
|---|---|---|---|---|---|---|---|---|
| cutthroat | 47 | 36-63 | 1501 | 1134-2027 | 135 | 59-205 | 32 | 2-85 |
| brook | 15 | 11-21 | 713 | 539-963 | 139 | 73-234 | 46 | 4-140 |
| TOTAL | 62 | 47-84 | 2214 | 1673-2990 | 136 | 59-234 | 36 | 2-140 |

Table 15. Population estimates and size of trout from a beaver pond in pond system 24, North Fork Snoqualmie basin.

| | $\hat{N}$ | $\hat{N}$ 95% confidence limits | Biomass (g) | Biomass 95% confidence limits (g) | Mean length (mm) | Length range (mm) | Mean weight (g) | Weight range (g) |
|---|---|---|---|---|---|---|---|---|
| cutthroat | 277 | 200-397 | 7552 | 5439-10826 | 129 | 66-255 | 27 | 5-177 |
| brook | 9 | 6-13 | 288 | 208-413 | 147 | 132-156 | 33 | 25-40 |
| TOTAL | 286 | 206-410 | 7840 | 5647-11239 | 130 | 66-255 | 27 | 5-177 |

decreased, anchor ice became less of a problem, and the depth and area of aquatic habitat increased. Although fewer kinds of benthic macroinvertebrates were found living in ponds, the standing crop was much greater than in the stream. Rainbow trout living in the ponds fed mainly on stream organisms that drifted into the ponds, but brook and brown trout fed mainly on pond organisms. (Since most ponds sampled in the North Fork basin were not fed directly by streams, i.e., other ponds directly abutted them, this might explain why rainbow trout were never caught in any of the ponds we sampled.) The higher standing crop of bottom fauna in the ponds was reflected in greater trout populations. These in turn resulted in a higher angler catch in the ponds than in the stream (Gard 1961). Beaver ponds differ from most western reservoirs by their relatively stable water levels and shallow average depths of 0.6 to 1.8 m (2 to 6 ft).

Cutthroat trout were the most common salmonid found in North Fork Snoqualmie ponds. In Spada Reservoir on the Sultan River, they fed heavily on lake benthos while rainbow trout relied more on stream-origin benthos (Washington Department of Game, Sultan River study, 1980). Cutthroat trout, as well as brook trout, are better adapted at foraging in ponds.

While minnow trapping, we also captured shorthead sculpins, northwestern salamanders, rough-skinned newts, and giant water bugs (Lethocerus americanus). The last is one of the largest aquatic insects in the United States and reaches a length of 70 mm (2.8 in) (Pennak 1978). They are fiercely predaceous, and feed on many kinds of aquatic organisms, including such relatively large forms as tadpoles, small frogs, and fishes.

Two identifying characteristics of shorthead sculpins are their palatine teeth and lack of a complete lateral line. We sent five beaver pond sculpins to Professor Carl Bond for positive identification. He reported that, "all appear to be shorthead sculpins (Cottus confusus) but the variation in them is remarkable. One lacks all signs of palatine teeth and, as you noted, one has a complete lateral line". This apparent evolutionary divergence is often the first step in speciation. It indicates that some beaver pond sculpin populations have been isolated from river populations for many (hundreds?) years.

**We have designated 32 pond systems containing 99 ponds in the North Fork Snoqualmie River basin (Photo 26). Twenty-six systems or 82 ponds are within the proposed reservoir's high pool elevation (Fig. 12, p. 32).**

Spring and early summer fishing success in North Fork Snoqualmie ponds was generally excellent, both for sports fishermen and us. Usually an angler's biggest problem was finding the ponds. The relative naivete of pond trout made our hook and line survey more effective by reducing strike variability. If trout were in a pond system, they usually were present in all ponds within that system.

Photo 26. Typical beaver *pond in* the North Fork Snoqualmie basin.

One pond system consisting of a single pond was discovered too late to be sampled. Of the remaining 98 ponds, we found trout in 58 ponds or 59.1 percent (Table 16). Of the 82 ponds sampled within the proposed reservoir site, 54 contained trout or 65.9 percent. Only 33 percent of 12 ponds above the reservoir site contained trout. A higher percentage of pond systems near the river contained fish than did those farther from the river (Table 16 and Fig. 12, p.32). This relationship suggests an interchange between some ponds and the river. In a few pond systems it could occur regularly. While in others, it probably occurs only during river flooding.

In ponds which we caught fish, 25 percent held both cutthroat and brook trout, 50 percent held only cutthroat trout and 25 percent held only brook trout. Cutthroat trout were the most frequently caught salmonid. Brook trout comprised only 3 percent of the known trout population in one of the two beaver ponds that were sampled with a fyke net. It is possible that low densities of brook trout (or other species) existed in some ponds but did not appear in our results.

Mean lengths of beaver pond trout (Table 16) ranged from 127 to 292 mm (5.0 to 11.4 in). However, hook and line sampling discriminates against smaller fish and thus actual mean lengths would be less. From our scale analysis, beaver pond cutthroat trout averaged 177 mm (7.0 in) at age 1+. Age 2+ fish averaged 269 mm (10.6 in). This growth rate was faster than that of river and stream fish. It probably reflects warmer pond temperatures as well as greater benthic invertebrate food abundance.

Trout population estimates for ponds systems which contained fish ranged from 35 to 2,262 fish (Table 17). The highest estimate was for system 31 which contains 12 ponds. The total trout population estimate for all 82 ponds within the proposed reservoir site was 8,250 fish. The 95 percent asymmetrical confidence limits were 5,997 and 11,755 fish.

Since trout have not been stocked in North Fork Snoqualmie ponds since 1974, present populations are self-sustaining. Cutthroat and brook trout usually spawn in gravel in moving water. Many North Fork Snoqualmie pond systems contain small gravel patches near their inlets or outlets. If only a few pairs of fish spawned successfully, it would be adequate to sustain populations. Brook trout have spawned in lakes in areas of upwelling (Scott and Crossman 1973). As mentioned, trout may be able to pass from the river or tributary streams into certain ponds. In some cases, this could occur most of the year, in others, only during high water.

Most North Fork Snoqualmie ponds without trout are probably limited by spawning habitat. With the exception of the two bog systems, they usually contain adequate juvenile and adult habit, but no spawning area. Most of these ponds would probably provide good fishing if regularly stocked.

Table 16. North Fork Snoqualmie pond systems sampled with hook and line during 1980 survey. Species information for systems in which no fish were caught was from 1979 fyke net and minnow trap studies.

| Pond system number | Number of ponds | Fish species known present | Mean length (mm) | Comments |
|---|---|---|---|---|
| 1 | 6 | --- | --- | Active beaver ponds. |
| 2 | 1 | --- | --- | --- |
| 3 | 6 | --- | --- | Above reservoir's high pool elevation. Large numbers of Northwestern salamanders. |
| 4 | 1 | cutthroat | 292 | Active beaver ponds. |
| 5 | 1 | --- | --- | Not sampled. |
| 6 | 1 | cutthroat | 201 | --- |
| 7 | 4 | brook | 226 | Above reservoir's high pool elevation. Shallow, with trout restricted to the few deep areas. No strikes in two ponds. |
| 8 | 2 | cutthroat | 193 | --- |
| 9 | 2 | cutthroat | 142 | --- |
| 10 | 2 | cutthroat | 184 | Active beaver ponds. |
| | | brook | 162 | --- |
| 11 | 1 | brook | 222 | Fitchener slough, brook trout caught in fyke net. Last planted with cutthroat trout in 1974, none caught. Active beaver lodge. |
| 12 | 1 | --- | --- | --- |
| 13 | 1 | cutthroat | 199 | Part of oxbow slough. |
| | | brook | 218 | --- |
| 14 | 1 | brook | 157 | --- |
| 15 | 1 | --- | --- | --- |
| 16 | 4 | --- | --- | Old beaver ponds with dark, tannin-stained water. |
| 17 | 8 | cutthroat | 135 | Sampled with fyke net and minnow traps in 1979 in addition to hook and line. No strikes in one pond. |
| | | brook | 139 | |
| 18 | 1 | ? | --- | Strikes, but no fish landed. |
| 19 | 2 | --- | --- | Above reservoir's high pool elevation. Active beaver ponds. |

Table 16. North Fork Snoqualmie pond systems sampled with hook and line during 1980 survey - continued.

| Pond system number | Number of ponds | Fish species known present | Mean length (mm) | Comments |
|---|---|---|---|---|
| 20 | 2 | --- | --- | Bogs. |
| 21 | 5 | --- | --- | Dark tannin-stained water. Amphibian egg masses present. Old beaver activity evident. |
| 22 | 2 | --- | --- | Dark tannin-stained water. |
| 23 | 8 | cutthroat | 127 | Newly constructed beaver ponds. No strikes in two ponds. |
| 24 | 5 | cutthroat | 129 | Sampled with fyke net and minnow traps in 1979 in addition to hook and line. No strikes in two ponds. Active beaver ponds. |
| | | brook | 147 | |
| | | shorthead sculpin | --- | |
| 25 | 2 | ? | --- | Strikes in one pond but no fish landed. No strikes in second pond. |
| 26 | 1 | --- | --- | Above reservoir's high pool elevation. Bog. |
| 27 | 2 | --- | --- | Above reservoir's high pool elevation. |
| 28 | 1 | --- | --- | Above reservoir's high pool elevation. |
| 29 | 9 | cutthroat | 167 | Active beaver ponds. |
| | | brook | 189 | |
| 30 | 2 | ? | --- | One strike, but no fish landed. |
| 31 | 12 | cutthroat | 182 | Oxbow slough system with beaver dams. |
| 32 | 2 | brook | 149 | Active beaver ponds. |

Table 17. Trout population estimates for pond systems sampled with hook and line in the North Fork Snoqualmie basin. Systems in which no trout were found are not listed.

| Pond system number | Number of ponds | Successful casts / total casts | $\hat{N}$ | $\hat{N}$ 95% confidence limits |
|---|---|---|---|---|
| 4 | 1 | 20/32 | 696 | 506-988 |
| 6 | 1 | 7/12 | 244 | 177-346 |
| 7 | 4 | 6/59 | 209 | 152-296 |
| 8 | 2 | 27/58 | 940 | 683-1334 |
| 9 | 2 | 41/66 | 1427 | 1037-2025 |
| 10 | 2 | 10/33 | 348 | 253-494 |
| 13 | 1 | 4/28 | 139 | 101-197 |
| 14 | 1 | 1/5 | 35 | 25-49 |
| 17 | 8 | 15/47 | 522 | 380-741 |
| 18 | 1 | 7/13 | 244 | 177-346 |
| 23 | 8 | 5/30 | 174 | 127-247 |
| 24 | 5 | 6/40 | 209 | 152-296 |
| 25 | 2 | 2/21 | 70 | 51-148 |
| 29 | 9 | 22/73 | 766 | 557-1087 |
| 30 | 2 | 1/24 | 35 | 25-49 |
| 31 | 12 | 65/103 | 2262 | 1645-3211 |
| 32 | 2 | 4/13 | 139 | 101-197 |

We set four 60-ft-long gillnets in Howard Hanson reservoir to obtain fish data for comparison with the proposed North Fork Snoqualmie reservoir. In one night we caught 31 of the following fish: rainbow trout, cutthroat trout, brook trout, mountain whitefish, and torrent sculpin. The cutthroat trout averaged 251 mm (9.9 in) and 225 g (7.9 oz) while the rainbow trout averaged 260 mm (10.2 in) and 255 g (9.0 oz). Results are presented in Appendix B.

## Angler Creel Census

The total number of anglers in 1979 decreased from summer to fall (Table 18). The average number of hours fished per angler peaked in July and then decreased (Table 19). Yet the best fishing was in August. Anglers caught 1.04 fish/hr and 4.67 fish/angler in that month compared to only 0.55 fish/hr and 3.04 fish/angler during July. The fishing pressure and success rate were lowest in October and November (Table 19).

We defined one angler use-day as one visit. A projected 1,245 angler use-days were spent on the river above the damsite and some of its adjacent beaver ponds (Table 20). Slightly over 3,500 trout were caught. Based on block netting results, those 3,500 trout were a mixture of cutthroat and rainbow with a small number of brook trout. The 4,032 fish caught below the damsite were almost exclusively rainbow trout. Only one whitefish was observed in the creel census. The one section of river that contained white fish was the lower 3.1 miles below the 3.0 to 4.6-m (10 to 15-ft) falls in Black Canyon (Fig. 3, p.14). We only had one creel census index station in this area, and it was not productive for whitefish angling. However, great numbers of whitefish were observed farther upstream during a snorkel survey (Table 7, p.82). We did not differentiate between cutthroat, rainbow, and brook trout because, especially with cutthroat and rainbow trout, many anglers did not know how to tell them apart. In addition, many people in the campgrounds had already eaten their catch by the time we interviewed them. A projected 2,648 angler use-days were spent fishing on the entire river. An estimated 7,569 trout were caught.

When we asked fishermen in 1979 if they would be fishing this area more often or less often in view of the gasoline shortage, 38.7 percent said more often, 33.9 percent no change, 22.6 percent less often, and 4.8 percent did not know.

While we did not ask anglers their place of residence, it probably followed a distribution similar to that of hunters questioned during deer season (Table 47, p. 203). Sixty-seven percent of the hunters were from the greater Seattle metropolitan area, and 19 percent were from local towns such as North Bend, Snoqualmie, and Fall City. The other 14 percent were mostly from Snohomish County, Pierce County, and outlying

Table 18. Number of anglers using the North Fork Snoqualmie River system, 1979.

| | Anglers above damsite | Anglers below damsite | Total anglers |
|---|---|---|---|
| May - June | 389.50 | 598.76 | 988.26 |
| July | 481.28 | 248.99 | 730.27 |
| August | 232.52 | 373.10 | 605.62 |
| September | 97.01 | 165.03 | 262.04 |
| October | 29.81 | 16.40 | 46.21 |
| November | 15.22 | 0.00 | 15.22 |

Table 19. Catch-per-unit-effort and angler effort in North Fork Snoqualmie river system, May - November 1979.

| | Average hours/ angler | Average fish/ hour | Average fish/ angler |
|---|---|---|---|
| May - June | 3.79 | 0.53 | 2.00 |
| July | 5.56 | 0.55 | 3.04 |
| August | 4.47 | 1.04 | 4.67 |
| September | 2.25 | 0.89 | 2.00 |
| October | 1.67 | 0.20 | 0.33 |
| November* | 1.67 | 0.20 | 0.33 |

* An insuffient number of complete trip anglers were interviewed. The October data are used as a best estimate.

Table 20. Summary of creel census in North Fork Snoqualmie River system, May-November 1979.

| | River above damsite | River below damsite | Total river |
|---|---|---|---|
| Total angler use-days | 1245.34 | 1402.28 | 2647.62 |
| Total fish | 3536.84 | 4032.30 | 7569.14 |
| Total angler hours | 5484.96 | 5720.15 | 11205.11 |
| Average hours/angler | 4.40 | 4.08 | 4.23 |
| Average fish/angler | 2.84 | 2.88 | 2.86 |
| Average fish/hour | 0.64 | 0.70 | 0.68 |

King county. Approximately 41.9 percent of all anglers talked to in 1979 were fishing the North Fork area for the first time.

Angler use will increase in the future as gasoline becomes less available, its price increases, and urban areas continue to grow.

The most frequent bait or lure used by anglers was salmon eggs (32.4%), followed by flies (31.7%), worms (19.4%), spinners (8.6%), and "other" (7.9%). The "other" category included such items as flatfish, bacon, marshmallows, cheese, and wild berries.

During both fishing and hunting seasons, we observed many visitors to the area not engaged in either of these activities. Some of these other recreationists were: campers, rock hounds, bird watchers, motor bikers, four-wheel-drive enthusiasts, mushroom pickers, nature photographers, gold panners, wood cutters, target shooters, kayakers, and berry pickers. Although no records were kept, we estimated that these other recreationists at least equaled the number of anglers and hunters and may have even exceeded them. As with angling, recreational use will continue to expand as population and gasoline prices increase because the project area is relatively close to metropolitan Seattle.

## Instream Flow

The IFG instream flow method quantifies potential habitat for different fish species at various life history stages, in a particular reach of stream, and at different discharges. Habitat is reported as "weighted useable area" per 1,000 ft of stream. We plotted curves of habitat availability versus discharge (Figs. 31 to 34). These curves model the following life history stages: 1) adult, 2) spawning, 3) juvenile, 4) fry, and 5) incubation. The peak of each curve represents the flow which maximizes potential fish habitat. Tables of habitat versus discharge, from which the curves were plotted, and tables of habitat as a percentage of wetted area versus discharge are presented in Appendix C.

The incubation curves as defined by the computer model, represent flows at which fish eggs would be covered with water, yet not subject to scour from moving gravel. Thus, theoretical amounts of habitat and peak flows for these incubation curves are usually greater than for other life stages (Figs. 31 to 33). From a practical view, however, the amount of incubation habitat cannot be greater than the amount of spawning habitat.

The amounts of habitat and peak (optimal) flows for fry and juvenile trout are generally less than for adult and incubation life stages. This reflects the preference of fry and juvenile trout for the limited amount of shallower and slower water along the shore.

Figure 31. Relationship between useable area and discharge for rainbow trout at station 1.

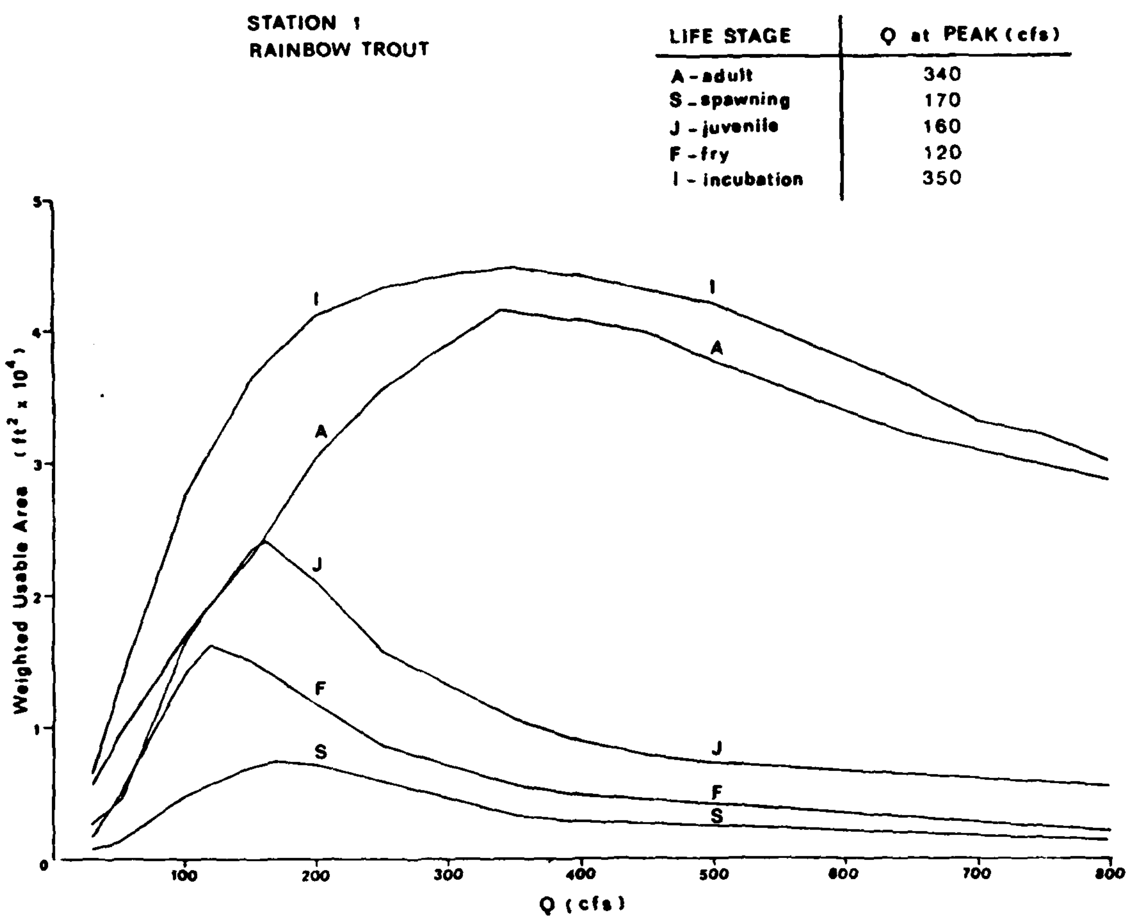
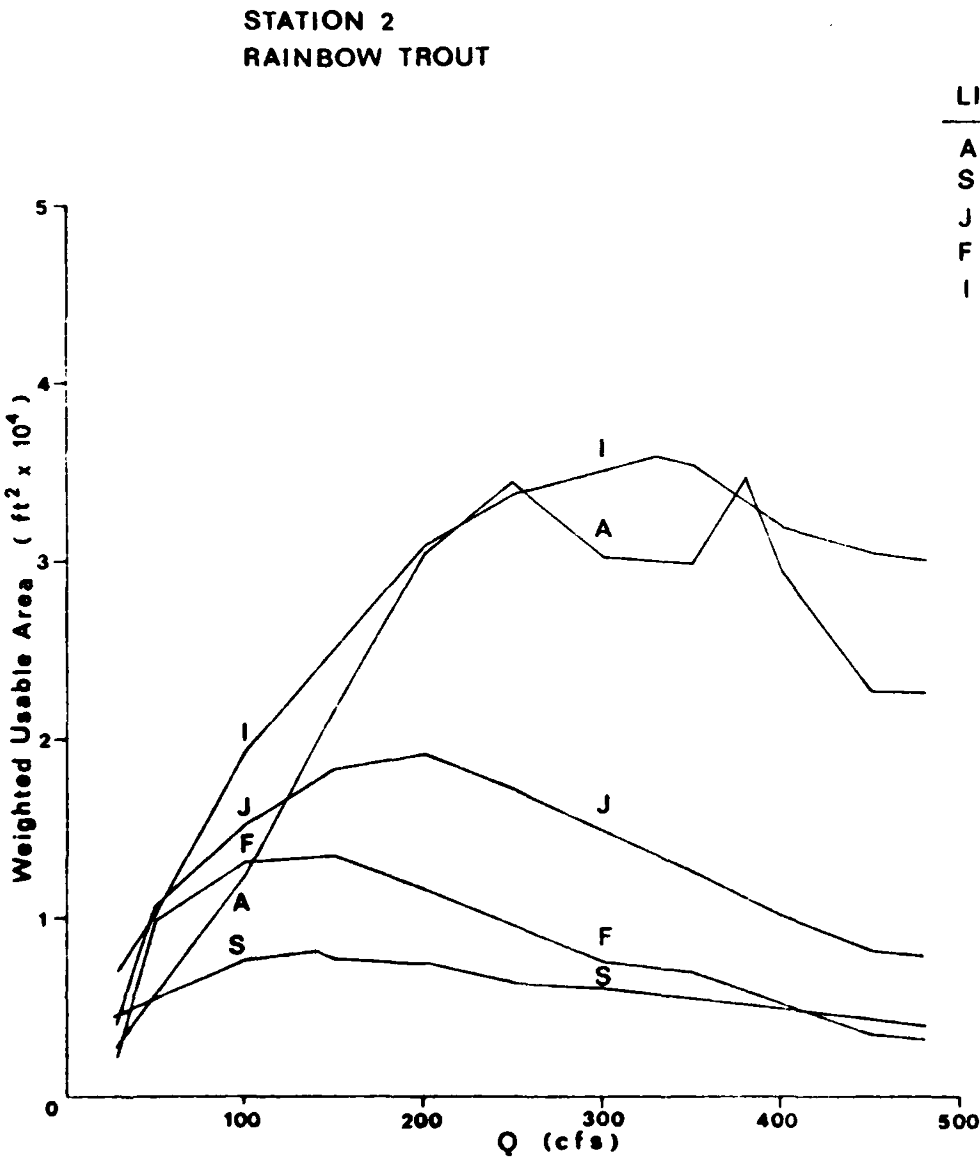


Figure 32. Relationship between useable area and discharge for rainbow trout at station 2.




| LIFE STAGE | Q at PEAK (cfs) |
|---|---|
| A - adult | 380 (240) |
| S - spawning | 140 |
| J - juvenile | 200 |
| F - fry | 150 |
| I - incubation | 330 |

Figure 33. Relationship between useable area and discharge for cutthroat trout at station 3.

STATION 3
CUTTHROAT TROUT

| LIFE STAGE | Q at PEAK (cfs) |
| --- | --- |
| A - adult | 170 |
| S - spawning | 130 |
| J - juvenile | 100 |
| F - fry | 40 |
| I - incubation | 220 |

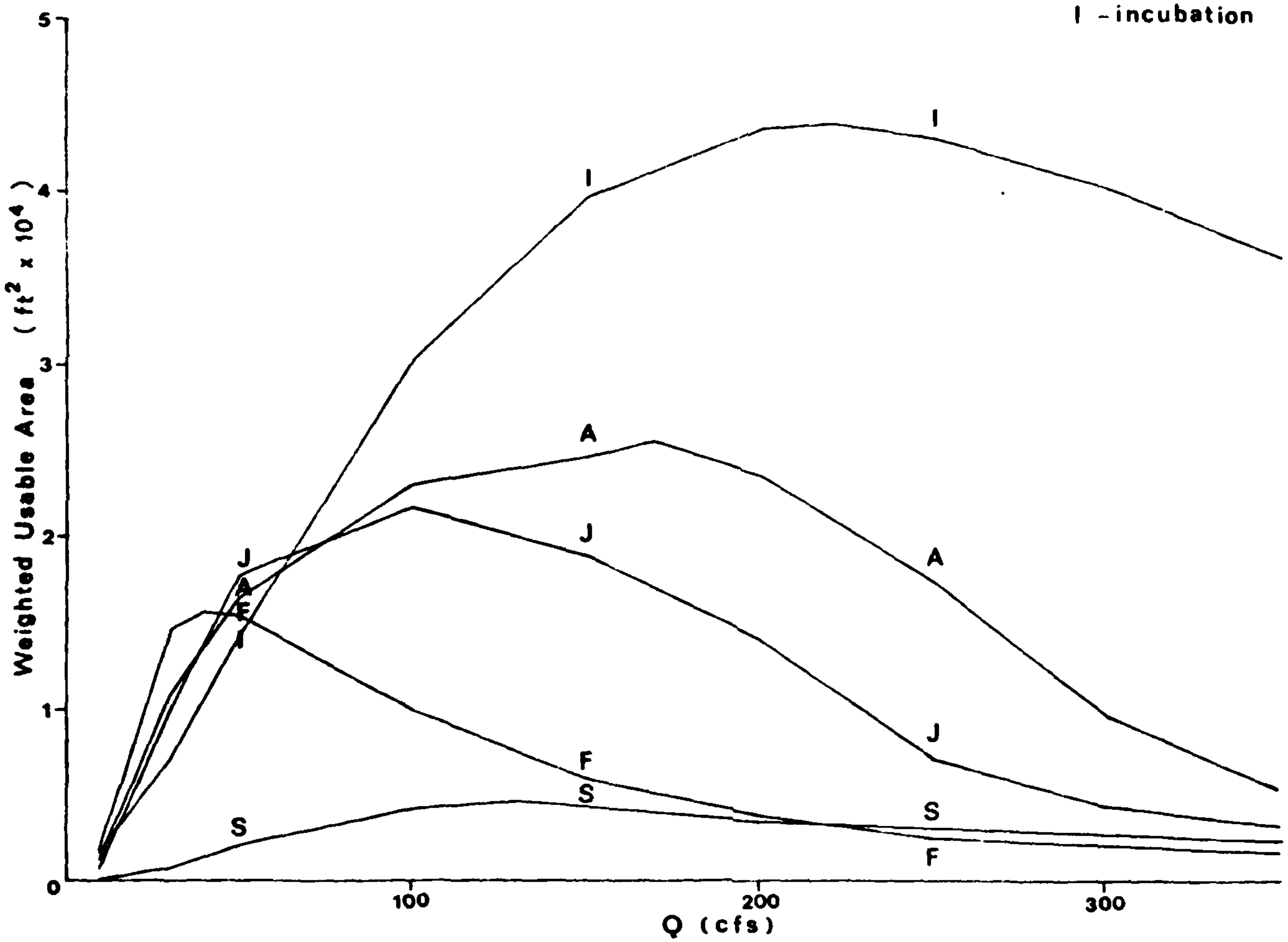
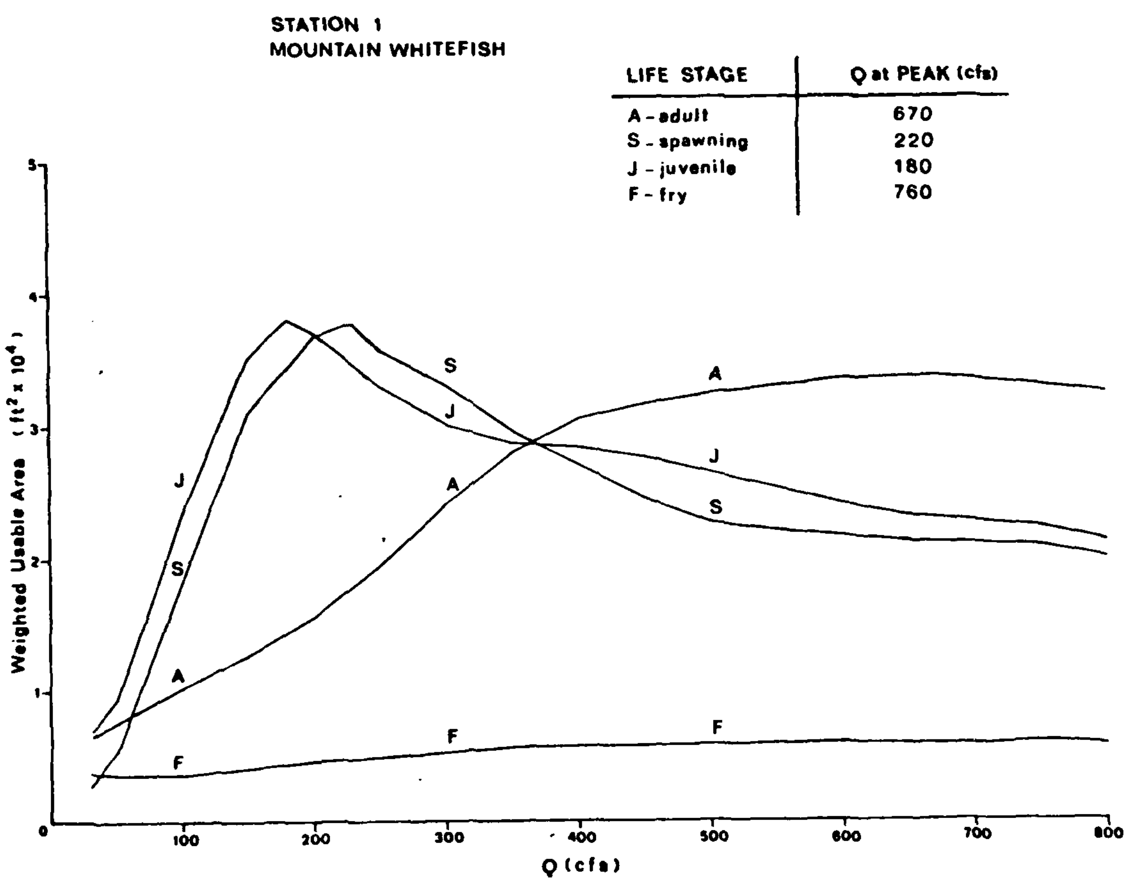


Figure 34. Relationship between useable area and discharge for mountain whitefish at station 1.



Spawning curves for trout at all three stations exhibit relatively small amounts of habitat (Figs. 31 to 33). However, trout spawning habitat in streams is rarely limiting in western Washington. Trout spawning habitat in the North Fork Snoqualmie River is adequate as shown by the large number of juvenile trout captured during 1979 electroshocking.

Adult trout are the life stage sought by anglers. The incubation, fry, and juvenile life stages are all dependent on an adequate number of adult trout. Fish greater than 200 mm (7.9 in.) long were usually age 2+ or more. The scales of an age 4+, female rainbow trout indicated that she had spawned for the first time at age 2+. Yet 95 percent or more of the trout captured in block net stations were less than 200 mm long. This was partly because large trout were more common in large pools, as we learned on snorkel surveys. We could not electroshock these pools due to their depth. Still, trout over 200 mm were greatly outnumbered by smaller fish.

For these reasons we believe the adult life stage should be considered most important in the Norh Fork Snoqualmie River. This is particularly true of the lower river beginning about one mile below Deep Creek (RM 10.1). Snorkel surveys revealed that these river sections contained the greatest numbers of 9 in. (229 mm) or larger trout per mile. The largest trout observed (20 in. or 508 mm) was also here, near the USGS gage (RM 9.2).

Instream flow stations 1 and 2 were both downstream from the proposed main reservoir (Fig. 14, p.37). Thus, they were the most important stations for determining optimum flows from the proposed dams. Station 1 was at Spur 10 bridge (RM 6.9), 1 mile above the proposed reregulating damsite (RM 5.9). Station 2 was at Wagner Campground (RM 11.7) below the proposed North Fork dam (RM 12.2).

During block-netting studies (Table 6, p.79), we determined that rainbow trout constituted 100 percent of the salmonid species composition in the river at station 1. Rainbow trout comprised 99 percent of the salmonid species composition at station 2. Mountain whitefish, although not found at either station, are present in the river below the migration barrier (RM 3.1) in Black Canyon. Therefore, at instream flow stations 1 and 2, we analyzed habitat versus discharge curves for only rainbow trout and mountain whitefish (Figs. 31, 32, and 34).

The peak adult flow for rainbow trout at station 1 (Spur 10 bridge) is 340 cfs (Fig. 31). The curve for adult rainbow trout at station 2 (Wagner Campground) has two peaks (Fig. 32). Both provide about the same amount of adult habitat. But since the lower one at 240 cfs also provides greater amounts of habitat for other life stages, it is preferable.

Peak (optimal) flows for the same species and life stage at different flow stations are not necessarily related. Each of the three

instream flow stations represerts different sections of river. A peak flow in one section of river may not be ideal for another river section. However, peak flows for adult rainbow trout at stations 1 and 2 do appear similar when extrapolated to a common midpoint. By correcting for major tributary inflow (assuming that Deep Creek is about the same size as Calligan Creek), both peaks can be extrapolated to approximately 290 cfs at the USGS gage (Table 21).

Mountain whitefish are present in the river below Black Canyon. However, life stage curves from station 1 (Fig. 34) are probably not directly applicable. The physical habitat of the river below Ernie's Grove is not represented accurately by station 1. In addition, we do not know which life stage is limiting in the mountain whitefish population. However, the general patterns displayed in Fig. 34 would probably occur downstream as well. To accurately assess whitefish instream flow needs, another flow study and electroshocking survey would have to be conducted in that part of the river.

Instream flow station 3 was near the upper end of the proposed reservoir at Mt. Phelps Campground (RM 19.2). Cutthroat trout comprised 85 to 99 percent of the salmonid species composition in the river nearby (Table 6, p.79). Thus, at this station we analyzed habitat versus discharge curves for only cutthroat trout (Fig. 33).

Because of its location, results from station 3 have no direct bearing on recommended flows below the damsite. The peak of the adult cutthroat trout life stage curve is 170 cfs (Fig. 33). This figure cannot be extrapolated downstream to station 2 because of the unknown inflow of streams and beaver ponds. However, at peak flows for fry, juvenile, and incubation life stages, a greater percentage of the total wetted area is available habitat, than at either station 1 or 2 (Appendix C). Though the amount of habitat is less, the wetted area can be used by fish more efficiently.

Table 21. Extrapolation of peak adult flows for rainbow trout at instream flow stations 1 and 2 to USGS gage at RM 9.2. The discharge of Deep Creek is assumed to be the same as that of Calligan Creek.

| Description | cfs |
|---|---|
| Peak Q at station 1 (RM 6.9) = | 340 |
| minus | |
| Mean annual Q of Calligan Creek (RM 8.6) = | -48 |
| equals | |
| Q at USGS gage (RM 9.2) = | 292 |
| | |
| Peak Q at station 2 (RM 11.7) = | 240 |
| plus | |
| Mean annual Q of Deep Creek (RM 11.2) = | + 48 |
| equals | |
| Q at USUGS gage (RM 9.2) = | 288 |

# IMPACTS

## Habitat

The river, streams, and ponds in the North Fork Snoqualmie basin would be replaced by a reservoir if the proposed project is implemented. Approximately 8.8 miles of river, about 3.0 miles of major tributary streams, and 82 ponds would be inundated.

We presented a description and operational plan for the proposed reservoir in the introduction to this report. Under normal conditions the proposed reservoir would be drawn down to a winter flood control pool at elevation 1482 ft (451.7 m). During late summer of unusually dry years the proposed reservoir could be drawn down to the riverbed. In either situation, most of the area exposed would probably be mud flats. Lindström (1973) called this area the aridal zone. The timing of reservoir fluctuations determines what, if any, natural vegetational colonization could occur in this zone.

The river flow through Black Canyon would be reduced to only 50 cfs by the diversion of most water to the downstream powerhouse (COE 1968). The historical minimum flow recorded nearby at Ernie's Grove was 54 cfs.

## Water Quantity and Quality

Typically, when a river is first impounded, there is an increased supply of nutrients leached into the water from the flooded vegetation and soil (Baxter and Glaude 1980). This results in an increased population of phytoplankton, zooplankton, and so on up the food chain. This post-impoundment nutrient pulse usually subsides within a few years. Because of the low nutrient status of its tributary streams, we predict the proposed North Fork Snoqualmie reservoir would be oligotrophic like the South Fork Tolt, Spada, and Chester Morse Reservoirs (all in western Washington). There are, however, other differences between these existing reservoirs.

The South Fork Tolt Reservoir is nearest (the next drainage basin to the north) and would probably be most similar to the proposed North Fork Snoqualmie reservoir. Physical characteristics of the South Fork Tolt Reservoir differ from those of Chester Morse (Olson 1978). In general, turbidity levels of the Tolt Reservoir exceed those of Chester Morse Reservoir. There ar a number of reasons for this. The watershed area is more abrupt than that of the Cedar and the slopes directly adjacent to the reservoir are steeper. The total precipitation is greater than that of the Cedar, a higher percentage of the watershed has been more recently logged, and the reservoir is of more recent origin, never having been a natural lake.

Shoreline materials are still in the process of washing into the depths of the South Fork Tolt Reservoir. Frequently, with strong east winds, a portion of the settled material is resuspended in the water column and turbidities exceed 2 JTU.

Slopes along the shore of the proposed North Fork Snoqualmie Reservoir consist of a variety of material subject to surface sloughing and some large-scale sliding could be expected (COE 1968). Turbidity levels would probably be similar to those occurring in the South Fork Tolt Reservoir.

Usually reservoirs act as settling basins and reduce downstream turbidity of the water. However, in reservoirs from which water is drawn from well below the surface, complex systems of horizontal currents may occur (Baxter and Glaude 1980). These complex currents are rarely, if ever found in natural lakes. If by virtue of its temperature or load of suspended material, the inflowing water is denser than the surface water, the two may not mix. This inflowing, cold, turbid water may pass directly through the reservoir, while the water lying above it moves very little.

Some management regimes may actually increase turbidity of the river downstream by discharge of turbid layers from the reservoir. It is occasionally the practice to discharge accumulated sediments from behind dams. This can result in deleterious effects on the river below (Hynes 1972). Spada Reservoir on the Sultan River is sometimes operated in this manner.

The South Fork Tolt, Spada, and Chester Morse Reservoirs are all saturated with oxygen throughout the water column, and the North Fork Snoqualmie would undoubtedly follow this pattern. Maximum surface temperature measured in the Tolt Reservoir in scattered samplings was 18.5°C (65°F) on 17 September 1974 (Olson 1978). It probably would be slightly higher if measured in mid-August. Maximum temperatures in Chester Morse Reservoir approach 19°C (66°F) in early August. Maximum temperature at lake bottom in 35 m (115 ft) of water is 8°C (46°F). The thermocline usually establishes itself at 9 m (30 ft).

The proposed North Fork Snoqualmie reservoir would not normally freeze over since most western Washington reservoirs at similar elevations usually do not.

The chief effect of the proposed reservoir would be to reduce winter high flows and possibly augment late summer and fall flows. This less violent flow pattern should reduce scour and gravel movement downstream. Information was not available on daily ramp (fluctuation) rates of the river or mean monthly flows.

The COE predicted downstream river temperature with the proposed North Fork Snoqualmie reservoir in place by comparisons with outflow

from Howard Hanson Reservoir on the Green River. During summer, water temperatures in the river below the proposed North Fork Reservoir at times could be 4 to 5° C (7.2 to 9.0°F) colder than at present (COE 1980a). During winter, the river at times could warm 3 to 4°C (5.4 to 7.2°F) above normal.

Presently, North Fork Snoqualmie River temperatures reach a maximum in late July or early August. The proposed reservoir would delay this yearly maximum about one month, postponing it to late August or early September.

As mentioned, a flow of only 50 cfs would be released into the river at Black Canyon between the reregulating dam at RM 5.9 and its powerhouse at RM 2.5 (COE 1968). The mean annual flow at Ernie's Grove at RM 2.2 is 699 CFS.

## Aquatic Macrophytes

The proposed North Fork Snoqualmie reservoir would probably eliminate most pond-dwelling aquatic macrophytes. Under natural conditions, the highest levels of water in lakes and ponds last only a few weeks, and drop before the growing season is far advanced. Thus, banks and shorelines are clothed during summer with their characteristic vegetation (Baxter and Glaude 1980). In a reservoir such as the proposed North Fork Snoqualmie, the water level will remain high during much of the growing season. Consequently, it may be surrounded during part of the year by a wide, virtually barren zone called the aridal (Lindström 1973). This area can be quite extensive if the surrounding relief is relatively flat and the fluctuation of the water level is substantial, as it would be in the proposed North Fork Snoqualmie reservoir.

Under these circumstances, natural restoration of aquatic or terrestrial vegetation is difficult. Aridal regions are unpleasant to look at and in dry weather may be the sources of large amounts of windblown dust. However, the aridal zone of the proposed North Fork Snoqualmie reservoir would not normally be exposed during summer, except in the uncommon instance when the reservoir does not reach full pool.

Wherever there was a seepage through the aridal zone, aquatic macrophytes could become established. This occurs in the aridal zone of Spada Reservoir on the Sultan River (pers. commun., Doug Wechsler, WDG, Seattle, Wash.).

If a dam reduces downstream flow fluctuations in a river, bed stability increases and is advantageous to aquatic macrophytes (Ward 1976a, Holmes and Whitton 1977, Haslam 1978). We discovered only two macrophytes growing in the river, and these were found only in very limited areas. Construction of a reregulating dam on the North Fork Snoqualmie River may increase species and numbers of macrophytes in the river downstream. This may also occur in the section of river between the two damsites, depending on flow stability.

## Benthos

### Reservoir

Conversion of a stream to a reservoir is a more drastic change than it may appear to the casual observer (McLachlan 1977). A number of studies has shown that after a new dam is built, the typical running-water benthic fauna is replaced by a lacustrine one (Hynes 1972). Many stream organisms cannot live in standing water and many standing water organisms cannot live in streams. For example, black fly larvae (Simulidae), which are common in the North Fork Snoqualmie River, can only live in running waters (Fredeen 1977). They would likely be replaced by lake-dwelling invertebrates such as leeches (Hirudinea), clams (Pelecypoda), burrowing mayflies (Ephemeridae), and water boatmen (Corixidae) to name but a few.

A few benthic forms can inhabit both streams and lakes. Certain species of midges (Chironomidae) inhabit running waters, while other species inhabit standing waters (Coffman 1978).

Different benthic invertebrates inhabit streams and lakes, partly because of the different way energy flows through each system. The predominate source of energy in standing water ecosystems is photosynthesis by phytoplankton. Stream ecosystems are largely nourished by organic detritus derived from terrestrial plants (Hynes 1975).

As mentioned in the Water Quality section, when a stream is impounded, an increased supply of nutrients is leached from the newly flooded soil and vegetation. Along with decreased flow rate, this allows an abundant population of phytoplankton and zooplankton to develop. This abundance is usually a short-term effect (Grimas 1962).

The benthic invertebrate population also greatly increases, using the resources of organic matter provided by flooded vegetation (Paterson and Fernando 1970). At first the makeup of the new benthic fauna is unstable and some organisms, especially chironomids, occur in great abundance. Typically, several years are needed before numbers decrease and some stability is attained (Hynes 1972).

Grimas (1961) found there was a tendency towards higher abundances of benthos in the vicinity of tributary stream inflows. The greatest benthic abundance found in Ross Lake was off the mouths of the tributaries (City of Seattle, Dept. of Lighting 1973). This reflects invertebrate drift from the streams as well as the richer supply of nutrients carried.

In lakes and nonfluctuating reservoirs, benthic invertebrates decrease in density from the littoral to the profundal (below the depth of effective light penetration) zone. But in fluctuating reservoirs the

greatest abundance of benthos is found immediately below the drawdown limit (Grimas 1961, Fillion 1967). Benthic production in the drawdown area is severely restricted by the absence of littoral vegetation and the periodic intervals of exposure.

Grimas (1961) conducted an intensive study on reservoir fluctuation effects in northern Sweden. Lake Blasjon, originally a natural lake, was dammed and had an annual drawdown of 5.5 vertical meters (18 ft). This drawdown exposed 11 percent (40 $km^2$) of the total bottom area of the lake. It reduced bottom fauna 70 percent in the exposed area and 25 percent in the remaining areas. The 30 percent survival rate in the exposed area was higher than expected because it was due in part to low temperatures and insulation provided by a thick ice cap that lasted all winter. These temperature conditions, for an extended period of time, would be rare in the North Fork Snoqualmie basin.

Researchers studying Ross Reservoir on the Skagit River concluded that greater reservoir drawdown resulted in fewer benthic organisms available to fish feeding in shallow waters when the reservoir was full (City of Seattle, Dept. of Lighting 1973).

Recolonization by benthos of the drawdown area took three months at Big Eau Pleine Reservoir in Wisconsin (Kaster and Jacobi 1978) and five months at Ross Lake. Since the proposed North Fork Snoqualmie reservoir would be at full pool for less than two months, benthic recolonization of shallower areas would not usually be total.

Downstream River

Growth, emergence, and fecundity of stream benthos are all temperature dependent (Hynes 1972). Numerous studies have shown that temperature changes below hypolimnial-release dams disrupt the normal life cycles of benthic invertebrates downstream (Hoffman and Kilambi 1971, Spence and Hynes 1971, Ward 1976b, Gore 1977).

During summer, water temperatures in the river below the proposed North Fork Snoqualmie reservoir at times could be 4 to 5°C (7.2 to 9.0°F) colder than at present (COE 1980a). Growth and maturation of most stream benthos are based on summation of total thermal energy over time (Ward and Stanford 1979). North Fork Snoqualmie River temperatures may be inadequate for completion of some invertebrate species' life cycles. For example, the elimination of most stoneflies from the tailwaters below Hungry Horse Reservoir in Montana could be explained by lack of an appropriate thermal regime (Elliott 1972). The time between oviposition and hatching, and length of the hatching period, were greatly extended by low summer temperatures. Reduced growth efficiency at low temperatures may delay emergence and cause reduced species biomass or even elimination of a species (Edington and Hildrew 1973). This sub-lethal effect can occur even though temperatures are within the tolerance of the organism. Summer temperatures reduced by only 4°C

($7.2^{o}F$) have been shown to reduce fecundity in mayflies, apparently by reducing size of adults (Sweeney 1978).

During winter, water temperatures in the river below the proposed North Fork Snoqualmie reservoir at times could be 3 to $4^{o}C$ (5.4 to $7.2^{o}F$) warmer than at present. Warmer temperatures could enhance growth of aquatic insect larvae that would normally emerge in spring. Adults may emerge early, when air temperatures are too low for survival or reproduction (Coutant 1968, Nebecker 1971).

Presently, North Fork Snoqualmie River temperatures reach a maximum in late July or early August. The proposed reservoir would delay this yearly maximum about one month until late August or early September. Delayed thermal maximums may retard or accelerate emergence, depending on the benthic species involved (Ward 1976b).

Many studies have demonstrated that the benthic community below deep-release dams is reduced in biomass or diversity, or both, as a result of the sublethal physiological effects described above. Ward and Stanford (1979) reviewed 12 studies. Species diversity was decreased in ten cases and standing crop was decreased in three cases by "summer cold-winter warm" thermal regimes. In the eight cases in which standing crop increased, it was due primarily to higher populatins of non-insects such as amphipods, isopods, molluscs, and annelid worms. These benthic invertebrates are less frequently eaten by trout (pers. comm., Alex Bradbury, WDG, Seattle, Wash.). However, true fly (Diptera) populations also increased, and they are an important food in trout diets.

Most studies cited here involved temperature changes more extreme than expected in the North Fork Snoqualmie River. But the trend toward lower community diversity and reduced populations of important fish food organisms may be realized even with the smaller temperature alterations and delayed thermal maximum predicted for the North Fork Snoqualmie.

Information on projected daily flow fluctuation rates downstream of the dam was not available. Natural seasonal and daily flow fluctuations usually occur gradually, allowing most benthic invertebrates to avoid stranding. Rapid flow fluctuations below dams strand benthos on the dewatered substrate and result in mortality through dessication or freezing. Gislason (1980) concluded that benthic insect fauna in shoreline areas of the Skagit River was significantly reduced compared to unregulated rivers such as the Sauk and Cascade. Degree of reduction was related to exposure time.

The upper Skagit River is regulated by hydroelectric dams, and flow fluctuations on the North Fork Snoqualmie River would likely not be as severe and thus as deleterious to benthos.

Ward (1976a) reviewed five studies of effects of flow constancy below dams on benthic standing crop and diversity. Standing crop was

enhanced in all cases, but diversity was usually reduced. He hypothesized that relatively constant and predictable conditions below some dams increase biotic interactions and lead to reduced species diversity. This could have a significant effect on fish populations since not all benthic species are equally available as fish food.

Flow constancy below the reregulation dam powerhouse at RM 2.5 would have a beneficial effect on standing crop. However, drastically reduced flows in the 3.4 miles of river between the reregulating dam and its powerhouse would decrease both standing crop and production in that river section.

## Fish

### Reservoir

When a stream is first impounded, there is often a rapid increase in the fish population. This is due to the post-impoundment nutrient pulse caused by decaying terrestrial vegetation and leaching from disturbed soils. A large population of zooplankton develops which is an additional fish food. Typically, this initial abundance is relatively short term and several years are needed before some population stability is obtained (Hynes 1972). In addition, some fish species appear to prefer streams to lakes. For example, the shorthead sculpin, while found in a few beaver ponds, is typically a stream fish (Wydoski and Whitney 1979) and probably would not do well in the proposed North Fork Snoqualmie reservoir.

To assess the potential fish population of the proposed North Fork Snoqualmie reservoir, we compared its physical characteristics to those of other reservoirs in western Washington (Table 22). The South Fork Tolt and Chester Morse Reservoirs are the closest in size and nearest in geographic location to the North Fork Snoqualmie basin.

Olson (1978) estimated that the South Fork Tolt Reservoir contained between 5,000 and 10,000 cutthroat trout. He estimated that Chester Morse Reservoir on the Cedar River contained approximately 20,000 rainbow trout and 35,000 Dolly Varden trout. Both reservoirs are closed to the public and are unfished.

In many western Washington reservoirs and lakes, trout grow larger and slightly more rapidly than in rivers at the same elevation. This also occurs in the North Fork Snoqualmie basin beaver ponds. Thus, the average size of trout in the proposed reservoir may be larger than in the river.

In all existing western Washington reservoirs listed in Table 22 adult trout populations are concentrated around the mouths of

Table 22. Physical characteristics of the proposed North Fork Snoqualmie reservoir compared to other existing western Washington reservoirs.

| Reservoir | Acres at high pool | Acres at normal low pool | Percentage of high pool area remaining | Acre-feet at high pool | Acre-feet at normal low pool | Percentage of high pool capacity remaining | Average annual drawdown (ft) |
|---|---|---|---|---|---|---|---|
| North Fork Snoqualmie (proposed) | 1,660 | 494 | 30 | 68,000 | 16,500 | 24 | 62 |
| South Fork Tolt | 1,025 | 890 | 87 | 57,000 | 38,000 | 67 | 20 |
| Spada | 770 | 560 | 73 | 35,600 | 18,950 | 53 | 22.4 |
| Howard Hanson | 780 | 0 | 0 | 26,000 | 0 | 0 | 71 |
| Chester Morse | 1,680 | ? | ? | 73,354 | 48,132 | 66 | 12 |
| Ross | 11,680 | 7,900 | 68 | 1,435,000 | 720,000 | 50 | 72.5 |

tributary streams. This is probably a feeding response to the high densities of benthic food organisms at the mouths of inlet streams (Grimas 1961, City of Seattle, Dept. of Lighting 1973). In the North Fork Snoqualmie reservoir, gatherings of adult trout would probably occur off the mouths of GF Creek, Philippa Creek, Sunday Creek, Lennox Creek, and the upper North Fork Snoqualmie River. Olson (1978) theorized that similar concentrations of fish in Chester Morse Reservoir could be cropped very heavily by anglers in a few seasons. A comparable situation might occur in the proposed North Fork Snoqualmie reservoir.

Water level fluctuations in the proposed North Fork Snoqualmie reservoir would have a greater effect on feeding of cutthroat than rainbow trout, based on stomach content analysis of 118 Spada Reservoir trout (WDG, Sultan River Study 1981). Cutthroat were more capable of exploiting lake-origin prey than rainbow. In late spring and early summer, rainbow ate primarily stream insects from tributaries (74% of diet), while cutthroat diet was 66 percent lake-origin prey. Lake-origin prey of cutthroat consisted mainly of bottom-dwellers, such as leeches, water boatmen, midge larvae, clams, and snails. In late summer and fall, both rainbow and cutthroat began eating terrestrial insects, and the stream component of their diets dropped to almost nothing. This was partly the result of a smaller benthic invertebrate biomass in the streams, which had been reduced by summer emergences. The lake-origin component of the rainbow diet rose to about 60 percent (mostly midge larvae and pupae), and cutthroat reliance on lake benthos remained at about 65 percent.

Other studies have shown snails and clams to be particularly vulnerable to reservoir drawdowns (Kaster and Jacobi 1978). Whereas Spada Lake rainbow rarely foraged directly on the bottom, cutthroat fed heavily on snails and clams. Leaches are also heavily used by cutthroat in the South Fork Tolt Reservoir (Congleton 1977). Although leeches are resistant to drying (Sawyer 1974), they are dependent on vegetation, debris, or rocks in the littoral zone (Pennak 1978) and would do poorly in the large mudflats caused by severe reservoir drawdown. The large size of leeches makes them an important food for cutthroat.

By contrast, the favored lake-origin food of rainbow are midge larvae (Chironomidae), which are among the macroinvertebrates least vulnerable (though they are reduced) to drying and freezing through stranding (Fillion 1967, Paterson and Fernando 1969).

The large drawdown of the proposed North Fork Snoqualmie reservoir, to some extent, would force rainbow and especially cutthroat trout to search for other food sources. They would probably rely more heavily on terrestrial insects and zooplankton. However, terrestrial insects are generally not available in winter and zooplankton would probably not compensate for the loss of the more substantial bottom food (Nilsson 1961). In addition, increased dependence of zooplankton raises the possibility of a fish tapeworm (<u>Diphyllobothrium</u> sp.) infection that now

plagues rainbows in Spada Reservoir and some other western Washington lakes. This parasite uses copepods as a first intermediate host and encysts in fish as next host. The final host is a fish-eating bird. This fish tapeworm is capable of causing significant mortalities in a fish population. However, it apparently does not occur in rainbow trout in Ross Reservoir.

Of importance to both rainbow and cutthroat is the decrease in chironomid species diversity as well as abundance. Several studies of reservoir drawdown show a reduction in species resulting in a few concentrated hatches of overwhelming numbers of chironomids that are underutilized by trout (Grimas 1961).

Nilsson (1961) found that reservoir fish lost weight as a result of benthos reductions during drawdowns. Grimas (1961) stated that reservoir drawdowns caused a reduced growth rate in fish. This was explained by a dietary change from a substantial, constantly available food to a less substantial, more occasional food.

Cutthroat and rainbow trout in reservoirs or lakes usually spawn and rear in tributary streams. In Chester Morse Reservoir, rainbow juveniles rear in tributary streams for 1 to 3 years (Wyman 1975). Growth during this period is slow and appears to be less than 4 in. during the first year. Congleton et al. (1977) captured no cutthroat trout from the Tolt Reservoir smaller than 170 to 180 mm (6.7 to 7.1 in). They concluded that juvenile cutthroat trout reside in tributary streams for 1 or 2 years (infrequently 3) before entering the reservoir. In Spada Reservoir, cutthroat and rainbow trout were usually greater than 200 mm (7.9 in) and rarely less than 170 mm (6.7 in) (WDG, Sultan River Study 1981).

A problem occurs in Chester Morse Reservoir for fish populations which spawn in either spring (rainbow) or fall (Dolly Varden). During and after rainbow peak spawning in April and early May, the reservoir water level rises about 5 ft. During and after Dolly Varden peak spawning in October, the reservoir water level rises about 9 ft. In both cases, this tends to flood the lower stretches of the tributary streams. As water is flooded back on these spawning areas, eggs and fry buried in the gravel suffocate because of lack of flowing water through the substrate. Cutthroat and rainbow trout from Spada Reservoir spawn in February and March (WDG, Sultan River Study 1981). By July, when trout fry emerge, the water level of Spada Reservoir has risen about 5 ft, as in Chester Morse Reservoir. Most cutthroat trout in the South Fork Tolt Reservoir spawn sometime before April (Congleton et al. 1977). From 1 February to 1 June, the water level of the Tolt Reservoir rises about 16 ft. No studies have been made, but suffocation of trout eggs is probably significant. In Ross Reservoir, rainbow trout peak spawning occurs from mid-May to mid-July (City of Seattle, Dept. of Lighting 1973). The reservoir's water level rises about 70 ft, usually from the beginning of May to mid-June. Many trout eggs deposited before mid-June

are suffocated by the rising waters. However, eggs deposited during the second half of the spawning season after mid-June are not killed.

The Green River immediately above Howard Hanson Dam alternates between a free-flowing river and a reservoir. The effect of this phenomenon on trout populations is unstudied, but many fishery biologists think it is detrimental. Between early spring and June, the water level of Howard Hanson Reservoir usually rises over 70 ft. This rise and the alternation between reservoir and free-flowing river, are probably strongly deleterious. Our one-day gillnetting in Howard Hanson Reservoir was conducted at a river mouth. This area would be expected to attract fish and our limited results were therefore inconclusive. A hydroacoustic survey of the entire reservoir would have been more useful.

Based on comparisons with Spada and South Fork Tolt Reservoir trout, cutthroat and rainbow in the proposed North Fork Snoqualmie reservoir would probably spawn in February and March, and fry would emerge in July. According to normal pool operation, the water level of the proposed reservoir would rise about 62 ft (elevation 1,470 to 1,532 ft, Fig. 5, p.17 and Table 22, p.124) from 1 March to 1 June. Due to this large rise and the timing of spawning and emergence, the negative effect on the proposed reservoir's trout population would be greater than for any reservoir already discussed, except possibly Howard Hanson. Of eggs laid in tributary streams at low pool during February and March, only those deposited above the June and July high pool elevation of 1,532 ft would avoid suffocation by the reservoir's rising water level.

This problem might be partially reduced by introducing into the proposed reservoir a rainbow trout stock which spawns at a later time. If the fish spawned in May and June instead of February and March, negative effects of the reservoir's drawdown on egg incubation could be attenuated.

We observed newly-constructed brook trout redds in the upper North Fork Snoqualmie River in early November 1979. Unlike Chester Morse Reservoir, the proposed North Fork Snoqualmie reservoir would not usually rise in the autumn. Instead, its level would drop until about 1 November and would not usually rise again (except during a severe winter storm) until almost April. Therefore, we would not expect brook trout spawning to be impacted as much as cutthroat and rainbow trout spawning.

In relatively dry years (30% chance) the reservoir's full pool elevation would not be achieved. In unusually dry years (2 percent chance) the reservoir would be completely emptied. More frequently there would be at least a small pool of water remaining. Mongillo and Faulconer (1980) studied effects of a severe drawdown on the kokanee population of Rimrock Reservoir on the Tieton River in Yakima County. The reservoir has been emptied completely only four times since impoundment over 50

years ago. Six million kokanee were estimated to inhabit the reservoir. When the reservoir was emptied in 1979, Mongillo and Faulconer estimated that 95 to 99 percent of the entire kokanee population was killed, mostly by being flushed from the reservoir. A few fish survived because a small pool at the base of the dam could not be emptied. Based on another complete reservoir evacuation in 1973, they concluded that it took the kokanee population 6 years to recover, even with some hatchery planting.

The Rimrock Reservoir example is not completely analogous to the situation in the proposed North Fork Snoqualmie reservoir. Unlike rainbow and cutthroat trout, kokanee need a lake environment to survive. However, we believe that total evacuation of the North Fork Snoqualmie reservoir would have a significant negative impact on its fish populations.

Table 23 rates tributaries of the proposed North Fork Snoqualmie reservoir for trout spawning and rearing potential. Spawning and rearing ratings were based on known and preferred habitat characteristics (Bovee 1978). In addition, ratings for juvenile trout rearing were based partly on our electroshocking results.

Since trout in the proposed reservoir would probably spawn in February and March at low pool and fry would not emerge until high pool in July, only those parts of tributary streams above high pool elevation would be available for successful spawning. Only the upper part of Sunday Creek and the upper North Fork Snoqualmie River were rated good for trout spawning (Table 23). GF, Philippa, and Lennox Creeks were considered poor because of the prevalence of large-sized substrate particles, high velocity boulder-filled rapids, or steep gradients which might prevent upstream spawning movements. Some of the excellent spawning habitat in lower GF and Sunday Creeks would be flooded even at the reservoir's low pool elevation (Table 23). Good spawning habitat would be flooded in Philippa Creek and the upper North Fork Snoqualmie River at the reservoir's high pool elevation.

Juvenile trout would rear in tributary streams year round. However, during most of summer when the reservoir would be at high pool, tributary stream rearing habitat would be restricted. Juvenile trout could not move upstream past rapids or small falls as easily as adults could. In addition, summer is the most important growth period. Some juvenile trout may enter the reservoir during high pool and re-enter the stream as the pool lowers. However, while in the reservoir they may be subject to predation by larger trout.

The best juvenile rearing habitat above the reservoir's high pool elevation is in the upper North Fork Snoqualmie River (Table 23). Here, an abundance of instream cover in the form of boulders and large organic debris, combines with many small "pocket" pools and rapids to create excellent juvenile habitat. During electroshocking surveys, we found

Table 23. Spawning and rearing potential for trout in tributaries of the proposed North Fork Snoqualmie reservoir.

| Stream | Spawning | Rearing |
|---|---|---|
| GF Creek | | |
| mouth to low pool elevation | excellent | excellent |
| low pool to high pool elevation | good | good |
| above high pool elevation to end of foot survey | poor | poor |
| Sunday Creek | | |
| mouth to low pool elevation | excellent | good |
| low pool to high pool elevation | excellent | good |
| above high pool elevation to end of foot survey | good | poor |
| Philippa Creek | | |
| mouth to low pool elevation | unflooded | unflooded |
| mouth to high pool elevation | good | good |
| above high pool elevation to end of foot survey | poor | fair |
| Lennox Creek | | |
| mouth to low pool elevation | unflooded | unflooded |
| mouth to high pool elevation | poor | poor |
| above high pool elevation to end of foot survey | poor | poor |
| North Fork Snoqualmie River | | |
| dam to low pool elevation | poor to excellent | poor to excellent |
| low pool to high pool elevation | good | good |
| above high pool elevation to end of foot survey | good | excellent |

juvenile trout abundance to be highest in the upper North Fork Snoqualmie of any tributary stream (Table 9, p. 88).

All tributaries except Lennox Creek contain good rearing areas between the reservoir's high and low pool elevations (Table 23). Above the reservoir's high pool elevation, GF, Sunday, Philippa, and Lennox creeks were rated poorly for rearing potential. Upper Sunday Creek, lower Lennox Creek, and to a lesser extent upper Philippa Creek, are notable for their almost total lack of instream cover. Upper Sunday Creek in particular, is characterized by a heavily braided channel (Photo 14, p. 50) with gravel or cobble riffles and few pools (Fig. 17, p. 49). Upper GF Creek provides poor juvenile rearing habitat because of its steep gradient which is characterized by numerous small falls and a few relatively large pools (these were better for adults than juveniles).

Olson (1978) roughly estimated that the South Fork Tolt Reservoir contained between 5,000 and 10,000 trout. By comparison, the proposed North Fork Snoqualmie reservoir would have a considerably smaller minimum pool size, and has much greater annual drawdown (Table 22, p. 124). The latter reduces benthic productivity in the reservoir, and can suffocate trout eggs in tributary streams as the water level rises in spring. Therefore, at most, we would anticipate a population of between 2,500 and 5,000 trout in the proposed North Fork Snoqualmie reservoir. If the proposed reservoir was closed to angling, it would probably support a viable trout population, just as in the South Fork Tolt and Chester Morse Reservoirs. However, if the proposed North Fork Snoqualmie reservoir was open to angling, as it probably would be, we conclude that present spawning and rearing potential of its tributaries would not sustain a fishery desirable to the average sportsman. A reasonable recreational fishery could only be maintained by annual plantings of hatchery trout.

Downstream River

During summer, water temperatures in the river downstream of the proposed North Fork Snoqualmie reservoir at times could be 4 to 5°C (7.2 to 9.0°F) colder than at present (COE 1980a). Salmonid growth rates are directly related to temperature and food supply. A decrease in temperature from 10 to 5°C (50 to 41°F) reduces the growth rate of juvenile salmon by nearly 50 percent (Brett et al. 1969). Colder summer temperatures below the proposed North Fork Snoqualmie dam could reduce the growth rate for rearing juvenile trout. However, warmer fall and early winter temperatures would tend to increase growth rates during that period.

Summer temperatures between 10.0 and 15.6°C (50 to 60°F) are considered optimal for rainbow trout (Scott and Crossman 1973). These temperatures were exceeded on several occasions in the North Fork Snoqualmie River during the summer of 1979. The proposed dam would

sometimes have a positive effect on rainbow trout in the downstream river by reducing these high temperatures.

During winter, water temperatures in the river downstream of the proposed North Fork Snoqualmie reservoir at times could be 3 to 4°C (5.4 to 7.2°F) warmer than at present. Rainbow and cutthroat trout presently spawn in February and March. Warmer winter temperatures could cause them to spawn earlier. Eggs which would be subjected to these increased temperatures could develop more quickly and this could lead to early fry emergence. If sufficient food is not available (because of early emergence from the stream by aquatic insects), increased fry mortality could result.

One of the chief effects of the proposed North Fork Snoqualmie reservoir would be to reduce winter high flows, and possibly augment late summer and fall flows. This less violent flow pattern should reduce scouring of trout eggs in the gravel and produce more optimum, fish habitat.

Information on daily flow fluctuation rates in the river downstream of the dam was not available. Natural seasonal and daily flow fluctuations usually occur gradually, allowing salmonid fry to avoid stranding. Rapid flow fluctuations below dams can strand and kill fry. It has been estimated that stranding of chinook salmon fry on the Skagit River below Gorge dam could lead to losses of up to 41 percent, with a range of 32 to 50 percent ($CH_2M$ Hill 1979).

As mentioned, Gislason (1980) concluded that severe flow fluctuations in the Skagit River significantly reduced benthic fauna in shoreline areas. During 1977 when the Skagit River fluctuated relatively little, insect production was higher than in 1976, when flows varied considerably. In 1977, chinook, coho, and steelhead fry were significantly bigger and in better condition than were fry sampled in 1976. Graybill et al. (1979) concluded that in years when flows fluctuated rapidly, lack of adequate food supplies may limit growth.

The upper Skagit River is regulated by hydroelectric dams, and flow fluctuations on the North Fork Snoqualmie River would probably not be as severe. Thus they would be less likely to cause frequent fry stranding.

Flows would be more constant in the short section of river below the reregulating dam powerhouse at RM 2.5. Stabilized flows could minimize fry stranding, have a beneficial effect on benthos standing crop, and lead to increased salmonid growth rates, when compared to the possible effects of rapidly fluctuating flows in the river between the two proposed reservoirs. However, drastically reduced flow (50 cfs) in the 3.4 miles of river between the reregulating dam and its powerhouse would severely decrease both insect standing crop and fish production in that river section.

## Angling

The effect of a reservoir on angler use in the North Fork Snoqualmie basin is difficult to predict. Use of reservoir water for municipal and industrial water supply could eliminate angler use if the reservoir is closed to public access. Or it could restrict angler use in some manner such as a ban on boats with motors.

The WDG conducted a creel census in 1979 and 1980 in Spada Reservoir on the Sultan River (WDG, Sultan River Study 1981). Spada Reservoir's high pool is less than half the size of the proposed North Fork Snoqualmie's (770 ac vs. 1,660 ac) and its average annual drawdown is 22.4 ft (6.8 m) compared to 62 ft (18.9 m) for the North Fork Snoqualmie (Table 22, p. 124). However, minimum pools of both reservoirs would be similar in size (Spada = 560 ac vs. NF = 494 ac) and about the same road distance from Seattle (Spada = 60 mi vs. NF = 50 mi).

The numbers of anglers fishing Spada Reservoir in 1979 and 1980 were 1.6 and 1.8 times greater than the number of anglers fishing the North Fork Snoqualmie River in the area of the proposed reservoir site in 1979 (Table 24). During 1979 and 1980 Spada Reservoir fishermen caught about 88 and 68 percent as many trout as fishermen caught on the North Fork Snoqualmie River at the proposed reservoir site; despite a 2-month shorter fishing season on Spada Reservoir. However, the additional angling on the North Fork Snoqualmie River was in October and November and these months accounted for less than 0.5 percent of the annual catch.

In 1979 the number of trout caught per angler in the North Fork Snoqualmie River was 1.8 times the trout per angler in Spada Reservoir in 1979 and 2.6 times that in 1980. In 1979 the number of trout caught per hour in the North Fork was 1.5 times the trout per hour in Spada Reservoir and 3.2 times that in 1980.

A better comparison could be made between the two systems if we had an estimate of angling use on the Sultan River before it was impounded. However, no estimate exists. Comparisons must be made cautiously. In addition, the North Fork Snoqualmie reservoir will probably not be as productive as Spada due to its larger drawdown.

The total angler-use of the proposed North Fork Snoqualmie reservoir site may increase significantly compared to present use by river anglers. However, quality of angling as measured by fish per angler and fish per hour may decrease substantially. The amount of stream fishing in the North Fork Snoqualmie basin will decrease. Some stream anglers will probably fish the reservoir, whereas others will go elsewhere. As state population expands, and the energy shortage gets worse, overall fishing pressure in the North Fork Snoqualmie basin will increase.

Table 24. Creel census results from the North Fork Snoqualmie River above Wagner Bridge compared to creel census results from Spada Reservoir on the Sultan River.

| Fishery | Year | Total anglers | Total trout | Trout per angler | Trout per hour |
|---|---|---|---|---|---|
| North Fork Snoqualmie above Wagner Bridge* | 1979 | 1,245 | 3,537 | 2.84 | 0.64 |
| Spada Reservoir | 1979 | 2,019 | 3,110 | 1.54 | 0.44 |
| Spada Reservoir | 1980 | 2,199 | 2,390 | 1.09 | 0.20 |

*Does not include tributary streams.

After two years of study in the North Fork Snoqualmie basin, our impression is that the numbers of fishermen and hunters is equaled or exceeded by those engaged in other recreation. The proposed reservoir would reduce some kinds of recreational activities while increasing others. We expect a future increase in overall recreation and urge that recreational benefits of the project be evaluated only after a thorough field study.

# TERRESTRIAL STUDIES

## METHODS

### Habitat Type Mapping

Before studying the biology of an area, it is often useful to map its major biological and man-made physical features. We refer to these features, such as plant communities, water bodies, and roads, as habitat types. A habitat type map illustrates kinds, amounts, and spatial relationships of potential wildlife habitats in an area. Investigators can use this information to predict kinds and amounts of wildlife using the area, and more importantly, to design biological studies to verify their predictions.

During our first year's studies, we described, mapped, and calculated acreages of habitat types within the boundary of the proposed North Fork Snoqualmie reservoir. Mapping was done from 1978 true color aerial photographs of the project area, and then transferred to overlays of 1:12,000 USGS base maps. We used a dot grid to calculate acreages of habitat types. Methods were described in detail in our 1980 report (Kurko et al. 1980, pp. 90-91).

In our second year's studies, we verified and corrected our habitat type map, based on new field observations (Photo 27). We also recalculated acreages of habitat types potentially inundated by the reservoir. This action was necessary because COE changed the maximum elevation of the proposed reservoir from 1,545 ft to 1,532 ft, reducing its surface acreage from 1,940 to 1,660. Acreage figures for inundated habitat types were used to estimate wildlife impacts of the proposed project, and to design adequate mitigation for lost wildlife.

### Mammal Studies

#### Small Mammals

Though usually viewed with little interest outside the scientific community, small mammals are an important part of terrestrial ecosystems. Through their food gathering activities, some small mammals, such as squirrels, play an important role in dispersing seeds of trees to potential germination sites. Other small mammals, like mice, feed on symbiotic fungi, distributing fungal spores to the forest floor through their feces. There, the fungi take up residence on roots of young conifers and other plants, helping them tap the soil's nutrients. Most small mammals are important as food for predators. Many of these predators (e.g., owls, coyotes) are aesthetically or economically valuable.

Photo 27. Game Department biologists verifying habitat map of proposed reservoir area.

Because of their ecological importance, small mammal studies were needed to better evaluate wildlife impacts of the proposed project.

To estimate their abundance in the project area, we livetrapped small mammals in eight habitat types (Fig. 35, Photo 28). Four habitat types were sampled in 1979, and four others in 1980. The first year we livetrapped during spring, summer, and fall. The second year we were limited to a single, summer trapping period (22-25 July).

Sample plots normally covered 1 ha (2.47 acres), with 100 traps placed in a 10 x 10 square grid pattern. However, three habitat types were too small for such an arrangement, so we distributed traps as follows: Bog--5 rows of 20 traps each; Marsh/Swamp--1 row of 16 traps and 1 row of 17 traps; Broadleaf Forest--10 rows of 6-10 traps each (totalling 75 traps). At all sites, traps were baited with birdseed, and spaced at 10-m (33-ft) intervals.

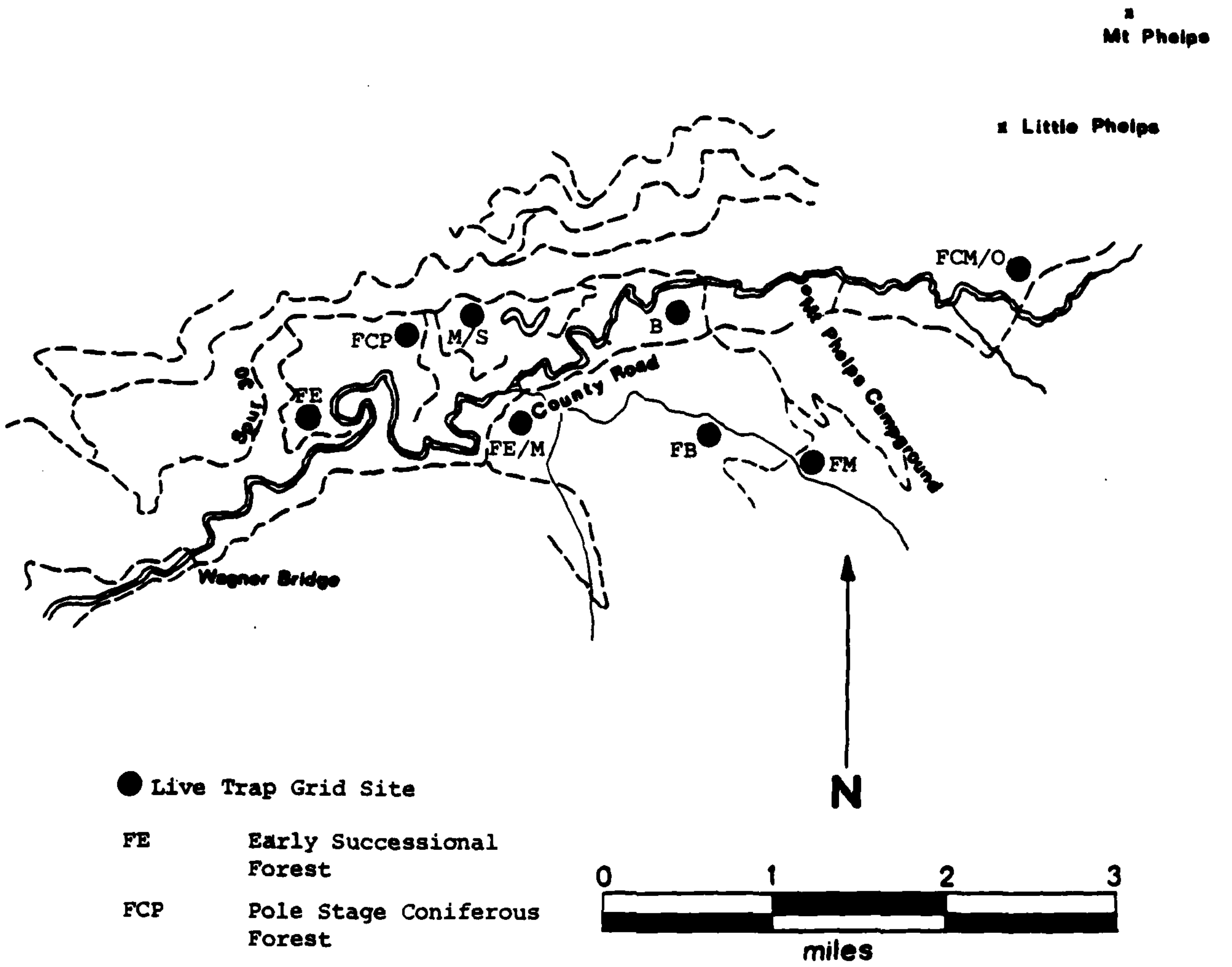
We livetrapped each site for three days per trapping period. Small mammals were individually marked by clipping a maximum of two toes. This is standard procedure in small mammal studies. Up to 99 individuals per grid could be identified in this manner. After marking each specimen, we noted its sex, approximate age (based upon size or pelage color), and breeding condition. When recaptured, only an animal's individual number was recorded.

We used the total number of individual small mammals captured on a grid, as our population estimate for that grid. Small mammals other than deer mice were seldom recaptured in numbers sufficient to permit population estimates by mark-recapture formulas. And when we were able to use these formulas to estimate small mammal numbers, our results were usually very close to the number of individuals captured. An added advantage of our method is that we avoided the large confidence intervals sometimes associated with mark-recapture estimates.

To illustrate the magnitude of impact of the proposed project on small mammals, we derived a rough estimate of the total number of small mammals that would be inundated by the reservoir. First, we multiplied our estimate of small mammal density for each habitat type, by the total area of that habitat type which would be inundated. Then, we added the resulting numbers for all habitat types to obtain an estimate of total number of small mammals.

Because we trapped only half the habitat types in either year, we combined trapping data for 1979 and 1980. We estimated only the summer small mammal population in this manner, because we did not trap all habitat types in other seasons. Nevertheless, within constraints discussed later (*see* Results and Discussion), we believe this method provides a rough, ballpark estimate of the number of small mammals within the area that would be inundated by the proposed reservoir.

Figure 35. Small mammal live trap grid sites, North Fork Snoqualmie basin, 1979-1980.




● Live Trap Grid Site

| | |
|---|---|
| FE | Early Successional Forest |
| FCP | Pole Stage Coniferous Forest |
| M/S | Marsh/Swamp |
| FE/M | Early Successional Forest/Marsh |
| B | Bog |
| FB | Broadleaf Forest |
| FM | Mixed Forest |
| FCM/O | Mature/Old Growth Coniferous Forest |

Photo 28. Baiting a live trap for small mammal studies. Habitat type is Early Successional Forest/Marsh.

Medium-sized Mammals

We obtained most of our knowledge of medium-sized mammals (snowshoe hare, mountain beaver, beaver, and river otter) in the area of the proposed project through general field observations, and conversations with Weyerhaeuser personnel and local trappers familiar with the North Fork Snoqualmie basin. WDG harvest records provided little specific information on furbearers in the project area. We were unable to conduct systematic winter mammal track counts as originally planned, because of infrequent snowfall at low elevations.

Large Mammals

Black-tailed Deer. A major goal of this study was to estimate the potential impact of the proposed North Fork Snoqualmie reservoir on black-tailed deer. Because food availability during winter usually regulates the level of deer populations (Leopold 1969), inundating a deer winter range would, in effect, eliminate the deer using that range. We therefore focused our studies on finding out how many deer winter in the project area, and where they go during summer.

To estimate the number of deer wintering within the boundary of the proposed reservoir, we used the pellet group count method. During the first week of December 1979, personnel from WDG, FWS, and COE helped us place 391 50-ft$^2$ circular plots along 29 compass lines crossing the project area (Fig. 36). Plots were spaced at random 10-90-m (33-295-ft) intervals, and marked with center stakes of 1.2-m (4-ft) steel reinforcing rod. Lines were spaced at roughly 0.5-km (0.3-mi) intervals, along roads running east-west through the project area. Lines and plots were liberally flagged to aid in finding them again. Distribution of sample plots conformed to a procedure known as "two-stage sampling with unequal-sized primary sampling units" (Freese 1962).

As workers laid out plots, they cleared them of existing deer pellets and recorded the number of groups cleared from each plot. A pellet group (3 or more pellets) was counted only if more than half the pellets lay within 1.2 m (4 ft) of the center stake.

During the first week in April 1980 (after snowmelt), we revisited the plots, counting numbers of deer pellet groups deposited since the plots were cleared. We then used the following formula to estimate the number of deer ($N$) wintering in the area potentially inundated.

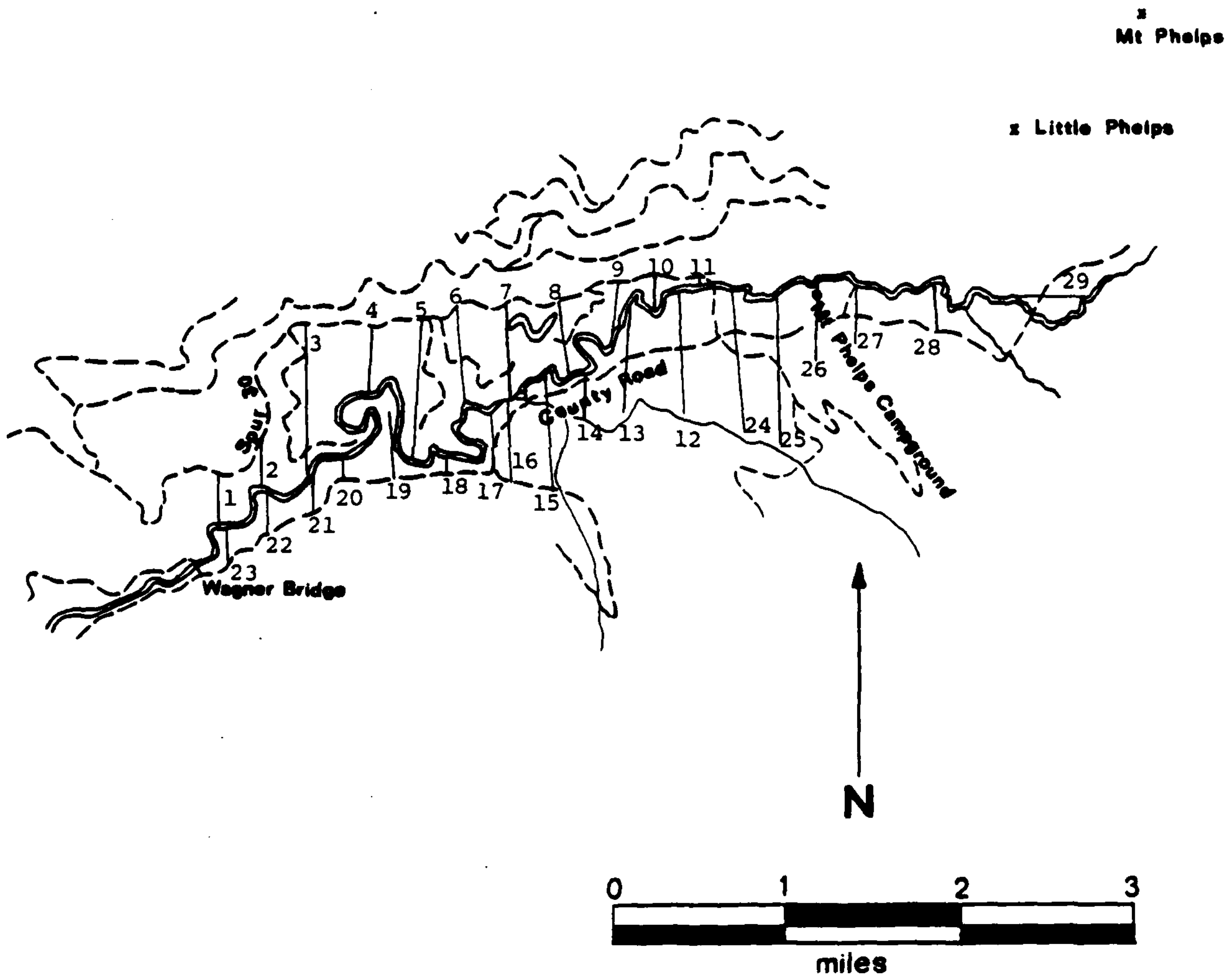
$$N = \frac{n}{d \times p} \times \frac{A}{a}$$

where $n$ = number of pellet groups counted

$d$ = defecation rate per deer per day

$p$ = deposition period (in days)

Figure 36. Locations of deer pellet transects in North Fork Snoqualmie basin, 1979-1980.



$A$ = acreage of proposed reservoir

$a$ = acreage of plots sampled

Confidence limits for $N$ were derived using Freese's (1962) formula for the standard error of $y$ (the mean number of pellet groups per plot), and multiplying the result by a $t$ value of 2.0. (By the Central Limit Theorem, $\bar{y}$ should be normally distributed.)

To determine whether the proposed reservoir would reduce seasonal deer populations outside the project area, a study of deer migratory habits was undertaken. From June through August 1979, we captured and marked five adult deer, one yearling, and two fawns in the area of the proposed project (Photo 29). We had hoped to mark animals earlier while they were on their winter or spring range, but our study began too late to do so. Adult and yearling deer were fitted with large, numbered collars and numbered ear tags. We attached only ear tags to fawns. Capture methods were detailed in our 1980 report (pp. 95-96).

Due to infrequent sightings of our visually marked animals, we were authorized to conduct radiotelemetric studies of deer movement, during the second year of our contract. From February through May 1980, we captured and fitted eight adult female deer with radiotransmitting collars (Telemetry Systems, Inc.). Frequencies ranged from 150.850 to 151.125 MHz.

In June 1980, we began radiolocating our deer, using a four-element hand-held yagi antenna. However, the single antenna was imprecise, and thus useful only when trying to walk in on a radiocollared animal. We therefore built and tested a truck-mounted antenna system, which greatly increased our range and accuracy. Structural and operating details of this system are described in Appendix E. Using the truck-mounted antenna (and the hand-held antenna for locating deer inaccessible by road), we monitored individual deer an average of once every two weeks from August through December 1980.

Other Large Mammals. We obtained much of our present knowledge of the status of mountain goat, black bear, bobcat, and cougar in the North Fork Snoqualmie basin, through conversations with WDG personnel and other individuals familiar with the area. Two persons provided us with reliable estimates of mountain goat numbers in the project area. The little information we have on bobcat and cougar was provided by hound-hunters and fur trappers. Our knowledge of black bears in the project area came from discussions with WDG employees and hound-hunters, and from WDG harvest records.

Photo 29. Measuring adult black-tailed deer captured for migration study.

During September 1979, we ran a roadside scent station transect to estimate relative abundance of coyotes in the area of the proposed project. Details of the method were given in our 1980 report (p. 99).

## Bird Studies

### Non-game Birds (Woodpeckers, Passerines, etc.)

Like small mammals, non-game birds are an important part of the forest ecosystem. Many of the plants whose fruits they consume, rely heavily on birds for seed dispersal. Non-game birds also devour large quantities of insects, and are themselves a major food of avian predators. Moreover, they are a great source of listening and viewing pleasure to humans. Because of their ecological and aesthetic values, non-game bird studies were included in evaluating wildlife impacts of the proposed project.

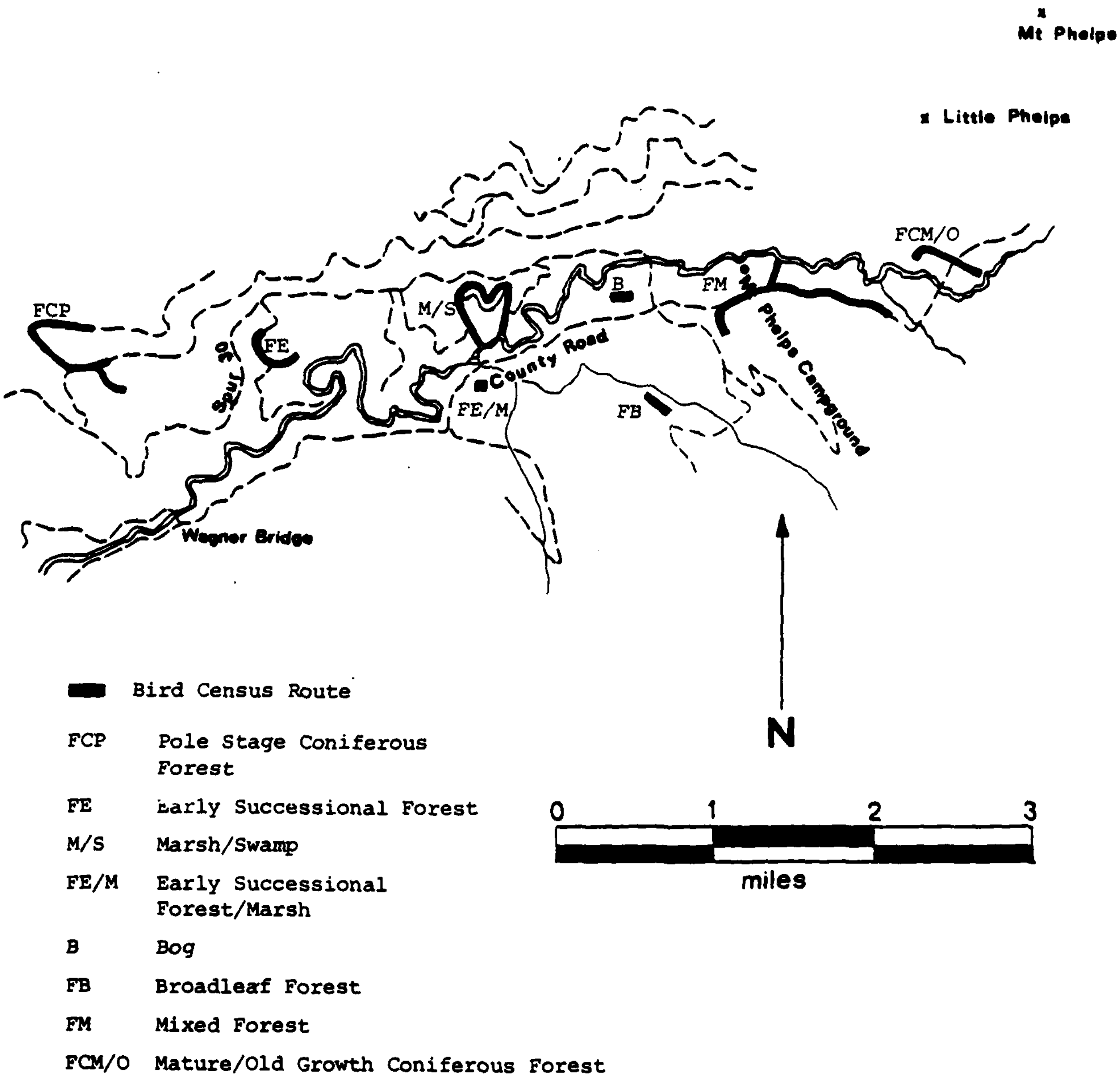
During 1979 and 1980, we censused non-game birds in eight habitat types in the area of the proposed project (Fig. 37). The first year, we censused four habitat types in May (spring migration), and five habitat types each in June and September (breeding season and fall migration). Persons from the Audubon Society, FWS, COE, and another WDG project assisted in these counts, which took place on two consecutive days each.

In 1980, we censused non-game birds in three other habitat types. However, we were limited to a single (summer) breeding census, which we conducted on only one day in each habitat type. Census dates were 24 June, and 2-3 July.

The method used to census non-game birds was the variable circular plot technique (Reynolds et al. 1980). Stations were marked at 200-m (656-ft) intervals along roads or other chosen routes. Numbers of stations varied from 1-14, depending on size and shape of the habitat unit sampled. Starting at or before sunrise, observers would walk their routes, stop at each station, and record the identity and estimated distance of every bird seen or heard within an eight minute span. For shorter routes, bird counts were repeated at each station to gather sufficient data (see Appendix G).

To estimate bird density by this method, the "detection distance" for each species is first determined. Detection distance is defined as the maximum distance at which all birds in a given habitat type are visible or audible. This distance is found by examining the frequency distribution of observations of a species at different distances, and noting the distance at which its density begins declining. Reynolds et al. (1980) gave a detailed explanation of this procedure.

Figure 37. Non-game bird census routes, North Fork Snoqualmie basin, 1979-1980.



After detection distance ($r$) has been determined, species density is calculated by summing the number of individuals counted within a circle of radius $r$, and dividing by the area of the circle. If only singing males were recorded, the number of birds can be doubled to account for both sexes.

To get an adequate frequency distribution for calculating detection distances, we combined species observations from different habitat types. This procedure has the advantage of reducing bias in distance estimation of different observers. We did, however, calculate separate detection distances for open vs. closed canopy habitat types. At least 10 observations were needed for an adequate frequency distribution, so we did not determine detection distances, or densities, for less common birds. Nevertheless, by summing densities for common species, we estimated overall seasonal bird densities in different habitat types.

As with small mammals, we used our census data to estimate the number of non-game birds whose habitat would be eliminated by the proposed reservoir. First, we multiplied estimated bird density in each habitat type, by the area of that habitat type which would be inundated. Then we added the resulting figures to obtain an estimated total number of non-game birds within the proposed reservoir boundary.

This procedure was possible only for estimating number of breeding birds, because summer was the only season in which we censused in all habitat types. Within constraints discussed later (see Results and Discussion), the method's main use is to illustrate the magnitude of impact of the proposed project on non-game birds.

## Game Birds

Grouse. In April 1979, we conducted a grouse census of the proposed project area. The method used to count grouse was similar to that for non-game birds. Starting just before sunrise, observers paced along roads in the project area, stopping every 200 m (656 ft) and recording numbers of hooting male blue grouse and drumming male ruffed grouse heard within a five minute period. A total of 44 listening stops were made.

The number of breeding male blue or ruffed grouse ($G$) in the proposed reservoir area was then estimated using the following formula.

$$G = n \times \frac{A}{a}$$

where $n$ = number of grouse heard

$A$ = acreage of proposed reservoir

$a$ = total hearing acreage of plots

Hearing acreage of plots is the number of listening stops, multiplied by the area of a circle with radius equal to the detection distance. For ruffed grouse in western Washington, detection distance is about 100 m (328 ft) (pers. commun., Leo Salo, WDG, Seattle, Wash.). We estimated the detection distance of blue grouse to be 200 m (656 ft).

Assuming an even sex ratio, we estimated the total adult grouse populations as $2G$.

Waterfowl. During 1979 field studies, we recorded all sightings of migrating or breeding ducks and swans in the project area. These data were supplemented by occasional aerial waterfowl surveys of the basin, conducted by FWS in connection with Snohomish River floodplain studies. Waterfowl sightings were tabulated by habitat type, to estimate their relative abundance and general patterns of habitat use. We used this information to estimate impacts of the proposed project to waterfowl, and to develop possible mitigation measures.

Band-tailed Pigeon. We obtained some information on band-tailed pigeon numbers in the project area during non-game bird censuses, and from miscellaneous field observations. Little useful information was available in WDG files.

### Raptors

Raptors (birds of prey) occupy terminal portions of the terrestrial food web. For this reason, they are relatively scarce compared to other birds. Because of their relative scarcity, as well as their unique physical abilities, many people find raptors fascinating.

Our work on raptors in the North Fork Snoqualmie basin was mostly limited to keeping detailed records of sightings, as well as locations of possible nesting activities in and around the proposed reservoir. On two evenings--one in March 1979, the other in March 1980--we drove and walked through the project area, attempting to elicit owl responses to tape recorded owl calls. Information derived from raptor observations was used to estimate potential project impacts to this important group of birds, and to help develop possible wildlife mitigation measures.

## Amphibian and Reptile Studies

Amphibians and reptiles have received little study in western Washington. As a result, their distribution and habitat preferences are not well understood. Nevertheless, like other small creatures, amphibians and reptiles play a role in cycling nutrients and transferring energy through aquatic and terrestrial food webs. During our field studies, for example, we found trout which had eaten amphibians. We also observed a fledgeling kestrel devouring a snake, which had been delivered by one of its parents.

Because of their ecological roles, as well as their intrinsic values, we felt we should at least document amphibians and reptiles in the project area. In March 1979, we spent one day visiting beaver ponds, bogs, and uplands, looking for amphibians. We also kept detailed notes on all amphibians observed in the basin during other field work. The information gathered was useful in anticipating potential impacts of the project to this interesting group of animals.

## Hunter and Trapper Use Studies

In anticipation of potential project impacts to hunters and trappers using the North Fork Snoqualmie basin, WDG received a small contract from the Pacific Northwest River Basins Commission in fall 1978, to conduct a detailed survey of deer hunter use of the basin and surrounding areas. Existing harvest information for deer and other terrestrial wildlife was also summarized from WDG files. We designed the present study of hunter and trapper use of the North Fork Snoqualmie basin to augment the previous year's study.

### Deer Hunter Use and Harvest

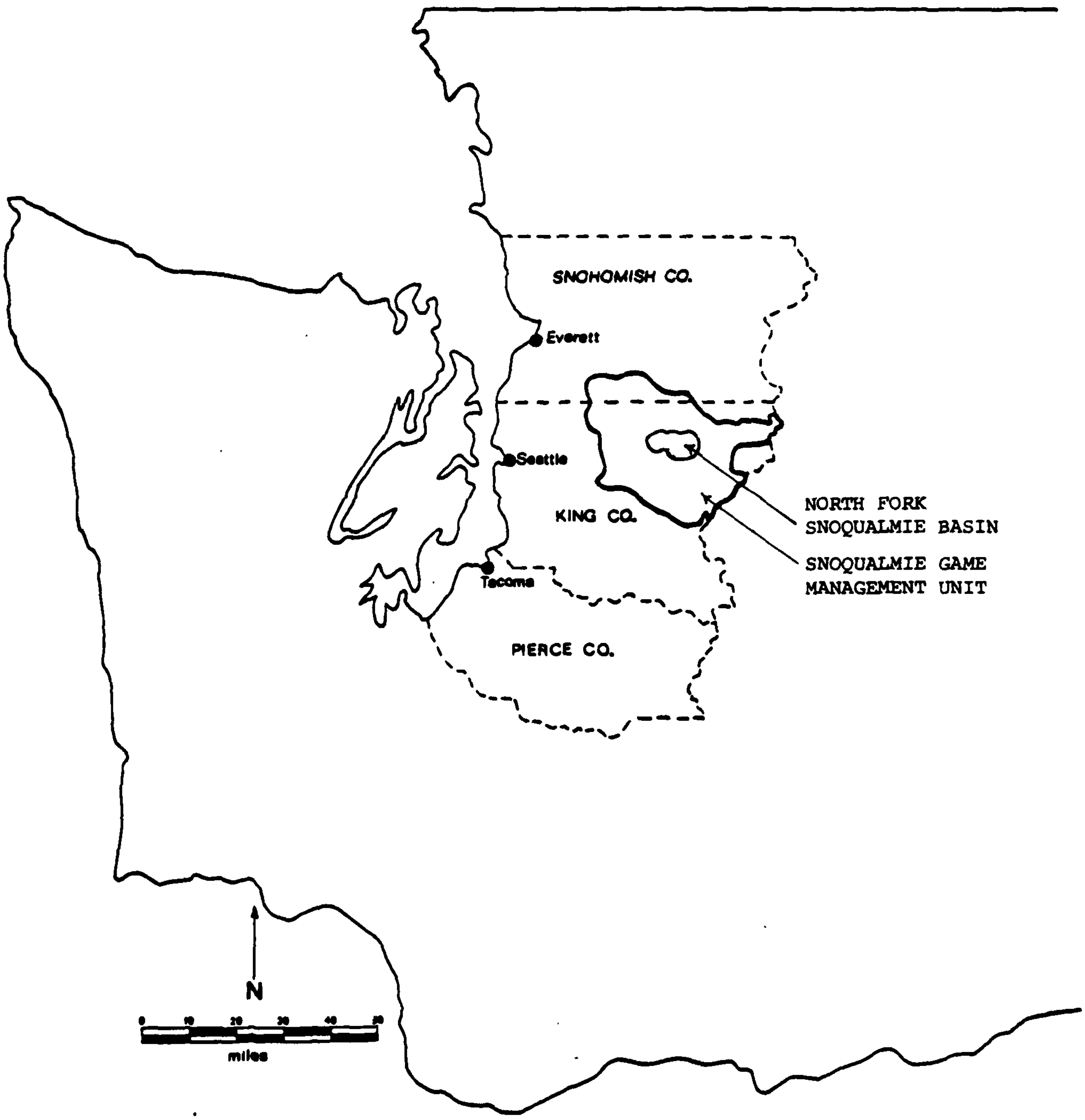
Since the early 1960s, WDG has monitored weekend deer harvest and number of hunters using the Snoqualmie Game Management Unit during deer hunting season. This unit encompasses the North Fork Snoqualmie basin and adjacent drainages (Fig. 38). On leaving the area, hunters are required to stop at a roadside checking station, and have their tags, licenses, and deer or other game animal (if they have one) examined. A tally of hunters and deer harvest is kept, and totaled at the end of the season.

During the 1979 deer hunting season, more complete information on hunter use and harvest was sought. We checked hunters on weekends <u>and</u> weekdays, recorded where they were hunting, and where they lived. This information allowed us to compare hunting success in the project area, with that for the rest of the management unit, and to determine who (geographically) was using the area.

### Other Hunter and Trapper Harvest

Information on harvest of mountain goat, black bear, coyote, bobcat, beaver, and grouse in the area of the proposed project was compiled mainly from WDG files and Big Game Status Reports. We supplemented these data with information obtained during conversations with local trappers and hound-hunters.

Figure 38. Location of North Fork Snoqualmie basin within the Snoqualmie Game Management Unit.



## Habitat Evaluation Procedures

Many values attributed to wildlife (aesthetic or ecological values, for example) are difficult to quantify. Therefore, past attempts to mitigate or compensate for wildlife losses resulting from a disruptive project have largely focused on game or commercial species, to which a dollar figure could be easily attached. Species without such dollar values, like small mammals, were usually ignored.

Recently, the concept that one species is more valuable than others has become outdated. Consequently, mitigation efforts are now being focused on habitats, which support groups of species. Spearheading this approach has been the development by FWS of the Habitat Evaluation Procedures (HEP). This method quantifies habitat values, based on assessed values of land cover types to groups of indicator species. A significant accomplishment of HEP is that it can quantify noneconomic values of wildlife resources.

The four steps of HEP are: 1) classification and mapping of habitat types in the area of interest; 2) selection of indicator animal species; 3) field evaluation of sample habitat types and calculation of a wildlife value (Habitat Suitability Index) for each habitat type; and 4) calculation of total habitat units in the area of interest (derived by multiplying the area of each habitat type by its Habitat Suitability Index, and summing the results).

Should the proposed dam and reservoir be authorized for construction, FWS and WDG will use HEP to help determine necessary wildlife mitigation. In preparation, WDG and COE assisted FWS in a HEP of the project area under baseline conditions, during September 1980. Results are forthcoming in a FWS Coordination Act Report. If the project is built, another HEP will be conducted, comparing total habitat units gained through mitigation, to those lost through project construction and operation. Should a deficit exist, WDG will propose new wildlife mitigation measures to eliminate this deficit. HEP can then be used again, to evaluate success of these new measures.

# RESULTS AND DISCUSSION

## Habitat Type Mapping

The North Fork Snoqualmie proposed reservoir area exhibits a variety of land cover unparalleled in other river valleys draining into the Snohomish River system. Unlike narrower neighboring valleys, the project area is broad and relatively flat, attesting to its lacustrine ancestry. For thousands of years, the river meandered through the old lakebed, carving numerous terraces and oxbows (Photo 1, p. 12). Ponds and wetlands now punctuate the landscape, creating openings in the forest and fostering growth of different plants than surrounding drier sites. Superimposed upon this natural habitat diversity is that created by logging. The result is a broad, terraced valley bottom, cloaked in a patchwork of small habitat units (see Map insert).

Table 25 shows acreages of habitat types within the proposed reservoir boundary. We used these figures, together with our field data, to estimate potential wildlife impacts of the proposed project.

## Mammal Studies

### Small Mammals

Our small mammal livetrapping studies yielded sufficient population data only for mice and insectivores (shrews and shrew-moles). Capture data for chipmunks, squirrels, and mustelids, while included in tables, were too few to indicate anything other than their presence on trap grids. Therefore, when referring to small mammals in this section, we mean mice and insectivores.

Results of our seasonal trapping studies during 1979 (Tables 26-28) indicated that in some habitat types, small mammal densities increased from spring through fall, while in other habitat types they did not. Spring (pre-breeding) populations were considerably lower than summer and fall populations in all habitat types sampled, except for Mature/Old Growth Coniferous Forest (Fig. 39). This result suggests that small mammal numbers fluctuate less in old growth forests, than in other habitat types. Such a hypothesis seems reasonable, in view of the great variety of microenvironments and year-round availability of seed-producing plants within the basin's old growth forest. A large population of small mammals during winter and early spring could make old growth coniferous forest especially attractive to predators such as owls and mustelids. However, longer studies are needed to verify these concepts.

In 1980, we livetrapped small mammals in previously unsampled habitat types, but only during summer. Our results (Table 29) showed higher

Table 25. Estimated acreages of habitat types within boundary of proposed North Fork Snoqualmie reservoir, 1980.

| Habitat Type | Acres | Hectares | Percent |
|---|---|---|---|
| Marsh/Swamp | 130.4 | 52.8 | 7.9 |
| Bog | 11.6 | 4.7 | 0.7 |
| Pond | 42.4 | 17.2 | 2.6 |
| River/Stream | 225.5 | 91.3 | 13.6 |
| Early Successional Forest/Marsh | 86.7 | 35.1 | 5.2 |
| Early Successional Forest | 292.3 | 118.3 | 17.6 |
| Pole Stage Coniferous Forest | 483.7 | 195.8 | 29.1 |
| Mature/Old Growth Coniferous Forest | 52.7 | 21.3 | 3.2 |
| Broadleaf Forest | 77.1 | 31.2 | 4.6 |
| Mixed Forest | 221.6 | 89.7 | 13.4 |
| Sand Slide | 7.7 | 3.1 | 0.5 |
| Logging Road | 28.3 | 11.5 | 1.7 |
| Total | 1,660.0 | 672.0 | 100.1 |

Table 26. Numbers of individual small mammals captured per hectare in four habitat types, North Fork Snoqualmie basin, April 1979.

| Species | Bog | Early Successional Forest | Pole Stage Coniferous Forest | Old Growth Coniferous Forest |
|---|---|---|---|---|
| Unidentified Shrew | | | 1 | 2 |
| Vagrant/Dusky Shrew | | 3 | | 1 |
| Trowbridge's Shrew | | | 1 | 1 |
| Deer Mouse | | 5 | 1 | 14 |
| Gapper's Red-backed Mouse | 1 | | 1 | |
| Creeping Vole | | | | 1 |
| Total | 1 | 8 | 4 | 19 |

Table 27. Numbers of individual small mammals captured per hectare in four habitat types, North Fork Snoqualmie basin, July 1979.

| Species | Bog | Early Successional Forest | Pole Stage Coniferous Forest | Old Growth Coniferous Forest |
|---|---|---|---|---|
| Vagrant/Dusky Shrew | 2 | 1 | 2 | 1 |
| Shrew-mole | | | | 1 |
| Deer Mouse | 5 | 10 | 9 | 12 |
| Creeping Vole | | 5 | | |
| Pacific Jumping Mouse | | | 2 | |
| Ermine | | 1 | | |
| Total | 7 | 17 | 13 | 14 |

Table 28. Numbers of individual small mammals captured per hectare in four habitat types, North Fork Snoqualmie basin, October 1979.

| Species | Bog | Early Successional Forest | Pole Stage Coniferous Forest | Old Growth Coniferous Forest |
|---|---|---|---|---|
| Unidentified Shrew | | | 1 | 1 |
| Vagrant/Dusky Shrew | | | 3 | |
| Shrew-mole | | | | 1 |
| Townsend's Chipmunk | | | | 1 |
| Douglas' Squirrel | | | | 1 |
| Deer Mouse | 2 | 25 | 15 | 17 |
| Townsend's Vole | 1 | | | |
| Creeping Vole | 1 | 4 | | |
| Total | 4 | 29 | 19 | 21 |

Figure 39. Numbers of individual insectivores and mice captured per hectare in four habitat types, North Fork Snoqualmie basin, Spring-Fall 1979.

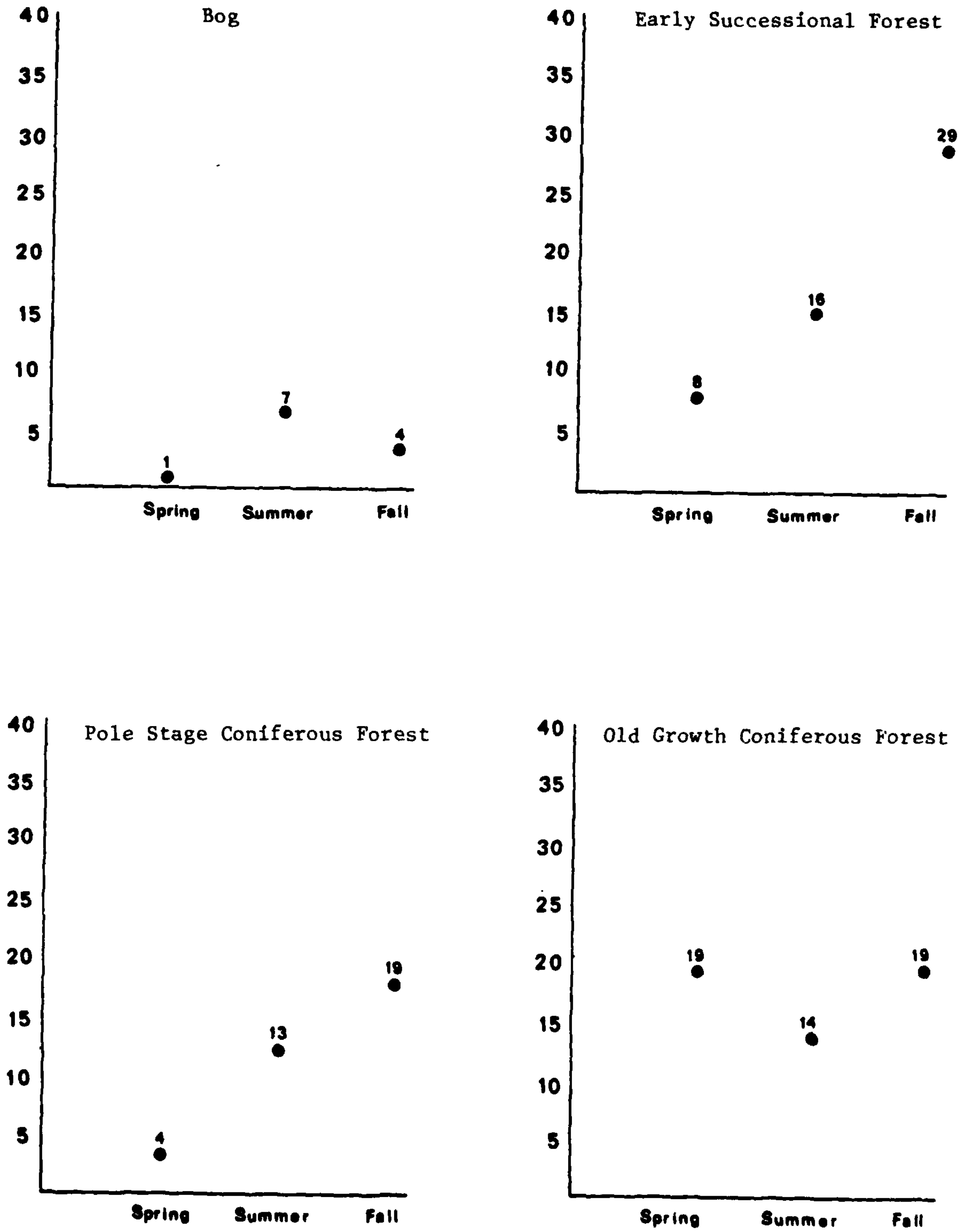


Table 29. Numbers of individual small mammals captured per hectare* in four habitat types, North Fork Snoqualmie basin, July 1980.

| Species | Marsh/ Swamp | Early Successional Forest/Marsh | Broadleaf Forest | Mixed Forest |
|---|---|---|---|---|
| Vagrant/Dusky Shrew | 6(2) | | 6.7(5) | 3 |
| Shrew-mole | | | | 1 |
| Townsend's Chipmunk | | | | 1 |
| Deer Mouse | 6(2) | 17 | 9.3(7) | 13 |
| Townsend's Vole | 3(1) | | | |
| Long-tailed Vole | | 1 | | 1 |
| Creeping Vole | 6(2) | 1 | | |
| Pacific Jumping Mouse | 6(2) | | | 1 |
| Short-tailed Weasel | | | 1.3(1) | |
| Total | 27(9) | 19 | 17.3(13) | 20 |

*Live trap grids covered 1/3 hectare in Marsh/Swamp and 3/4 hectare in Broadleaf Forest habitat types. Numbers of small mammals captured in these two types (in parentheses) are therefore expanded to show numbers per hectare.

small mammal densities, than in habitat types sampled during summer 1979 (Table 27). Some of this difference may be due to a general increase in small mammal abundance in 1980. WDG biologists studying small mammals in the Sultan basin documented such an increase between 1979 and 1980 (pers. commun., John Dragavon, WDG, Seattle, Wash.). It is also possible that habitat types sampled during 1980 normally support more small mammals, at least during summer. Our highest small mammal density occurred around the edge of a beaver pond, a habitat type designated as Marsh/Swamp. Small mammal densities in the Sultan basin were also highest around the perimeter of a beaver pond, (pers. commun., John Dragavon, WDG, Seattle, Wash.). The role of sampling error in explaining density differences for the two years is apparently minor, because these differences were consistent.

Results of livetrapping for both 1979 and 1980 indicate that deer mice outnumbered other small mammals in most habitat types during most seasons (Tables 26-29). Exceptions were Pole Stage Coniferous Forest in spring, and Marsh/Swamp in summer. The high diversity and density of small mammals in the Marsh/Swamp community suggest that a variety of predators of small mammals find good hunting around beaver ponds in summer (Photo 30).

Extrapolating our figures for numbers of mice and insectivores captured in each habitat type (see Methods, p. 137), we derived a minimum, summer estimate for number of small mammals within the boundary of the proposed reservoir (Table 30). According to this procedure, summer habitats of at least 9,100 small mammals would be inundated if a reservoir were built. Of course, number of small mammals within the boundary of the project area changes seasonally and annually. Forest succession causes further changes. Our purpose in deriving a single estimate of small mammal abundance is to approximate the average, baseline ("without project") condition of this important group of animals. Impacts are then assessed by comparing known baseline conditions, to conditions expected to occur with the project.

## Medium-sized Mammals

We obtained most of our information on mountain beaver, snowshoe hare, river otter, and beaver in the project area from conversations with individuals familiar with the area. Joe Greenhaw (pers. commun., Weyerhaeuser Co., Snoqualmie, Wash.), who has done mark-recapture studies of mountain beaver on the Snoqualmie Tree Farm, felt that mountain beavers might reach densities of 10 to 15 per ha (4-6 per acre) in the study area. For the basin as a whole, however, mountain beaver densities are probably much lower (pers. commun., James Rochelle, Weyerhaeuser Co., Centralia, Wash.). Our field observations of burrows suggest that mountain beavers are most concentrated on slopes in early successional forest, particularly where the ground is wet from seeps.

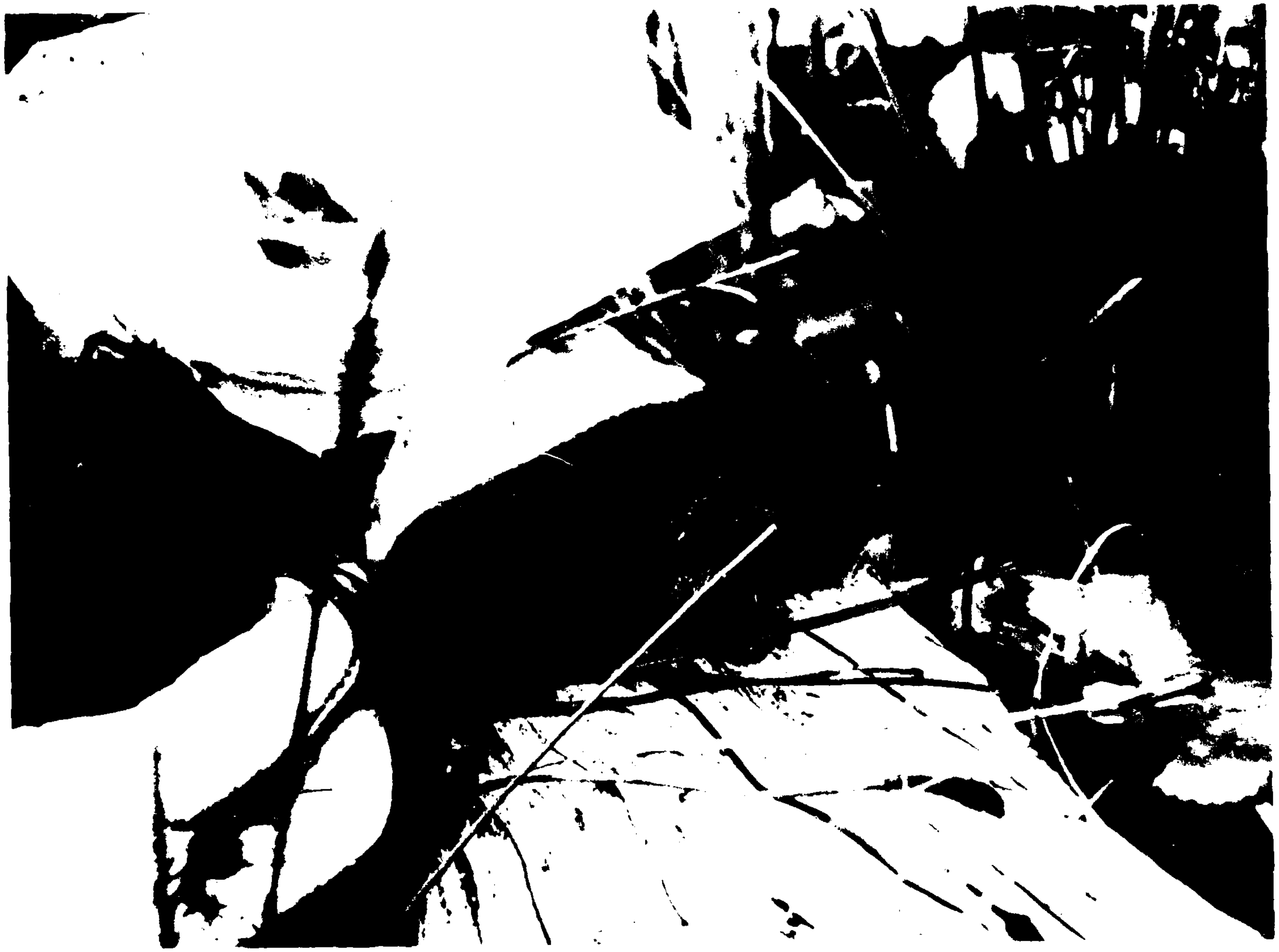


Photo 30. Long-tailed vole, one of the small mammals hunted by wetland predators.

Table 30. Minimum estimate of number of mice and insectivores within proposed reservoir boundary, North Fork Snoqualmie basin, July 1979 and 1980.

| Habitat Type | Hectares | Small Mammals per Hectare | Total Small Mammals |
|---|---|---|---|
| Marsh/Swamp | 52.8 | 27 | 1,425.6 |
| Bog | 4.7 | 7 | 32.9 |
| Pond* | 17.2 | - | - |
| River/Stream* | 91.3 | - | - |
| Early Successional Forest/Marsh | 35.1 | 19 | 666.9 |
| Early Successional Forest | 118.3 | 16 | 1,892.8 |
| Pole Stage Coniferous Forest | 195.8 | 13 | 2,545.4 |
| Mature/Old Growth Coniferous Forest | 21.3 | 14 | 298.2 |
| Broadleaf Forest | 31.2 | 16 | 499.2 |
| Mixed Forest | 89.7 | 20 | 1,794.0 |
| Sand Slide* | 3.1 | - | - |
| Logging Road* | 11.5 | - | - |
| Total | 672.0 | | 9,155.0 |

*Habitat type not sampled.

Our general impression of snowshoe hares in the basin is that they are abundant. When we conducted our deer pellet group counts, we found hare pellets most frequently in young forest with an open canopy.

We have no first-hand knowledge of river otter abundance in the study area. However, one individual who has trapped the area for many years, believes there is a stable population of 3-4 family groups (10-14 otters) within the proposed reservoir boundary (pers. commun., Fred Lawrence, Snoqualmie, Wash.).

One of the more interesting physical features of the North Fork Snoqualmie basin is the large number of ponds, marshes, and swamps. Many of these areas have been created and maintained, or enhanced by beaver damming. While these wetlands comprise a relatively small proportion of the total area within the proposed reservoir boundary (Table 25, p. 152), they play a large part in producing the tremendous heterogeneity of vegetative cover occurring in the basin (Photo 31).

Aerial photographs and field surveys of the project area indicate at least 26 separate pond systems within the proposed reservoir boundary. Approximately one-third of these ponds is active (presently supporting beavers). We know of five active beaver lodges (Photo 32). Undoubtedly, there are several lodges yet to be found. We also suspect that beavers live in banks along slow stretches of the river and in some pond banks. Such areas are indicated where concentrations of beaver droppings occur in deep river pools and pond bottoms, but where there are no known lodges. In view of these observations, we think that one trapper's estimate of 75 beavers living within the boundary of the proposed reservoir (pers. commun., Fred Lawrence, Snoqualmie, Wash.) is reliable, if slightly conservative.

## Large Mammals

Black-tailed Deer. Results of our pellet group count during spring 1980 indicate that the project area is prime winter-spring range for black-tailed deer. We estimate that an average of 352 deer occupied the area within the proposed reservoir boundary, from December 1979 through March 1980. The 95 percent confidence interval for this estimate is 232-472 deer. We derived our population estimate by applying values from our pellet group count to the formula for $N$, number of wintering deer.

$$N = \frac{n}{d \times p} \times \frac{A}{a}$$

where $n$, number of pellet groups counted = 176

$d$, defecation rate per deer per day = 13 (Fairbanks 1979)

$p$, deposition period (in days) = 123

Photo 31. Diversity of vegetation around a beaver pond.

Photo 32. Beaver lodge in the proposed reservoir area. Cuttings in foreground are remains of a winter food cache.

$A$, acreage of proposed reservoir = 1,435*

$a$, acreage of plots sampled = 0.4488062

Derivation of confidence limits for $N$ was described in Methods (p. 142).

Winter densities of black-tailed deer as high as those in the project area--61 $\pm$ 21 deer/km$^2$ (157 $\pm$ 54 deer/mi$^2$)--have not been reported elsewhere. Hines (1975) observed fall deer densities in the Tillamook Burn, Oregon, of up to 61/km$^2$ (158/mi$^2$), but this was for an enclosed population. Maximum deer density observed outside the enclosure was 36/km$^2$ (93/mi$^2$), during summer. Reported winter densities of black-tailed deer in western Washington, range from 39/km$^2$ (102/mi$^2$) along the Cowlitz and Cispus rivers (Wood et al. 1980), to 4/km$^2$ (11/mi$^2$) around Chester Morse Lake (Schoen 1976). Features which probably distinguish the project area as outstanding winter-spring deer habitat are its tremendous variety of cover and food, coupled with relatively mild winters. Nearly everywhere on the valley floor, a deer should be able to satisfy its needs within a small area.

Through our radiotelemetric studies, we identified both migratory and resident deer in the project area (Fig. 40). Migratory deer have separate seasonal home ranges, while seasonal home ranges of resident deer overlap.

Biologists have traditionally considered only two such ranges for deer--a summer and a winter home range. However, Harestad (1979), working with black-tailed deer on northern Vancouver Island, identified a third seasonal home range occupied during spring. The spring range generally overlapped, or was close to the winter home range, suggesting that it could have been overlooked in other studies.

Because we had very few winter and spring locations for our radiocollared deer, we grouped these two categories, and distinguished them from summer locations. We defined the winter-spring period as 15 October-14 May, and summer as 15 May-14 October. Of course, not every deer restricted its seasonal home range use to these dates.

All our radiocollared deer were females. On the basis of body size, pelage, and in a few cases, tooth wear, we also judged them all to be adults, at least 2 1/2 years old. Two of our animals, #5A and #3A,

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*We did not attempt to count pellet groups in River/Stream habitat, and therefore excluded its 225 acres in estimating the deer population.

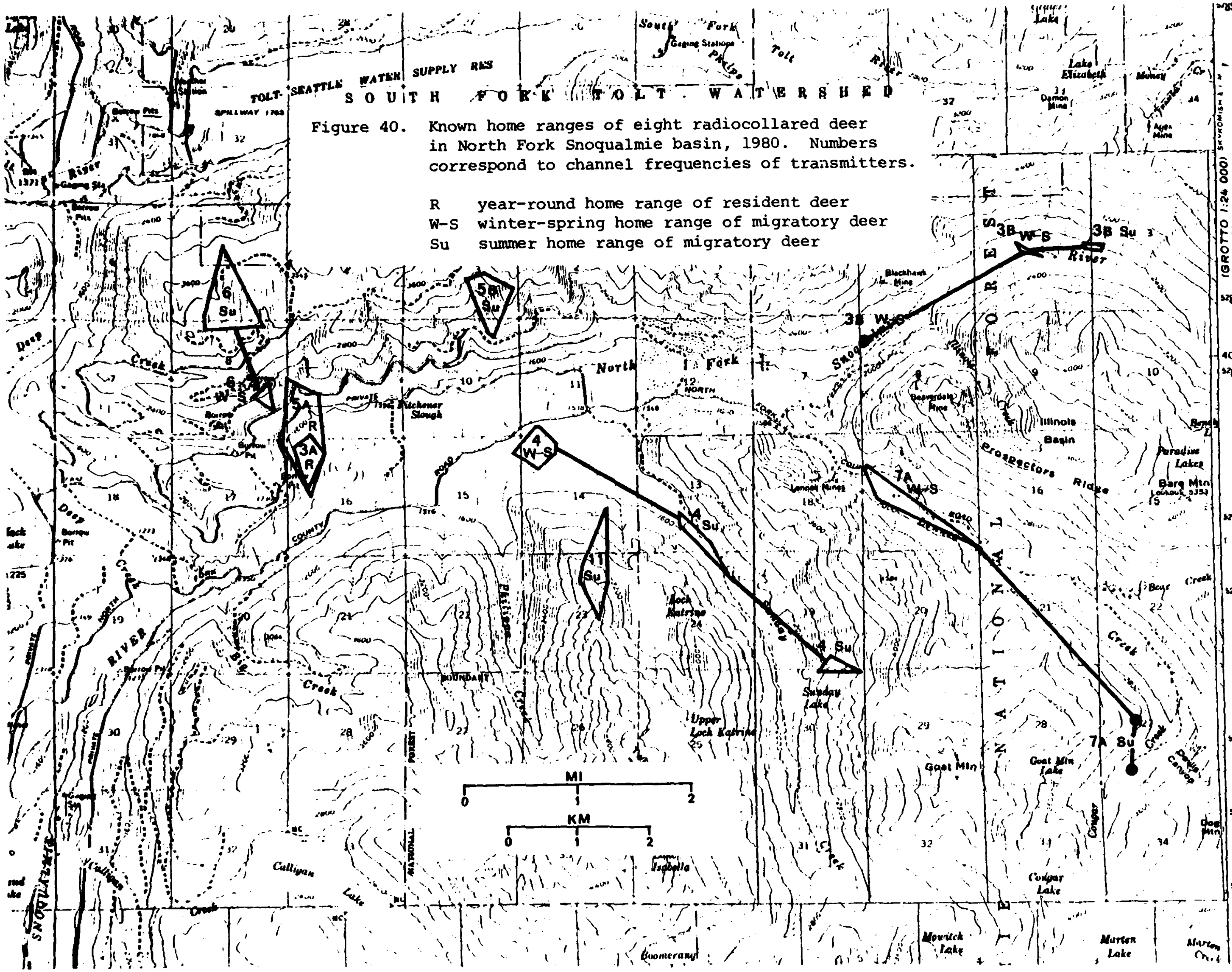



Figure 40. Known home ranges of eight radiocollared deer in North Fork Snoqualmie basin, 1980. Numbers correspond to channel frequencies of transmitters.

R year-round home range of resident deer
W-S winter-spring home range of migratory deer
Su summer home range of migratory deer

were residents, having remained in the same general location since we marked them in February and April 1980 (Figs. 41 and 42).

Winter-spring home ranges of both resident animals appeared to be centered at slightly higher elevations than their summer home ranges, which were partly within the proposed reservoir boundary. Harestad (1979) also noted that winter ranges of his two marked resident deer were slightly higher than their summer ranges. However, spring ranges were at the same level, or lower than their summer ranges. Deer undoubtedly key their home ranges to habitat, rather than just to elevation. Habitat is influenced by elevation, but also by other factors such as logging. Thus, we should not necessarily expect the same movement patterns in areas which have been differently influenced by man.

Our remaining six radiocollared deer appeared to be migratory animals. However, seasonal movement patterns are not well established for all these animals, because we lack sufficient winter-spring locations.

One deer whose migratory status is well established is #11. We marked her on 15 May at about 550 m (1,800 ft) el., overlooking Sunday Creek (Fig. 43). Thereafter, she moved upslope, summering above Loch Katrine at elevations between 823 and 1,219 m (2,700-4,000 ft). On 12 June, we observed her with her fawn at about 1,036 m (3,400 ft) el.

Sometime between mid-September and mid-October, #11 moved out of the basin. We were unable to receive her signal again until late November, when we triangulated her position to the Moss Lake area, 18 km (11.2 mi) northwest of her summer range (Fig. 44). To get there she must have crossed the North Fork Snoqualmie and Tolt rivers, and several minor drainages, dropping over 760 m (2,500 ft) elevation. Two subsequent radiolocations near Moss Lake suggest she will remain there for the winter, and perhaps spring.

Though dramatic, the migration of #11 may not be unusual. A deer we equipped with a numbered collar during summer 1979 was seen several times the following winter, approximately 13 km (8 mi) northwest of where we had marked her. The next summer (1980) we again observed this animal, back in the North Fork Snoqualmie basin. Two other winter sightings of collared deer--one in a field between Carnation and Fall City, the other near Snoqualmie Falls--also suggest long summer-winter migration. Similar movements of radiocollared deer have been documented in the Sultan basin, as well (pers. commun., John Dragavon, WDG, Seattle, Wash.). We suspect that radiocollared deer #5B, which disappeared from her summer range in mid-October (Fig. 45) has likewise moved to her wintering area, beyond the range of our monitoring equipment.

The rest of our radiocollared deer were captured during spring, near or within the proposed reservoir boundary, and moved upstream or

Figure 41. Radiolocations of resident deer #5A, North Fork Snoqualmie basin, February - December 1980.

■ winter-spring location
● summer location

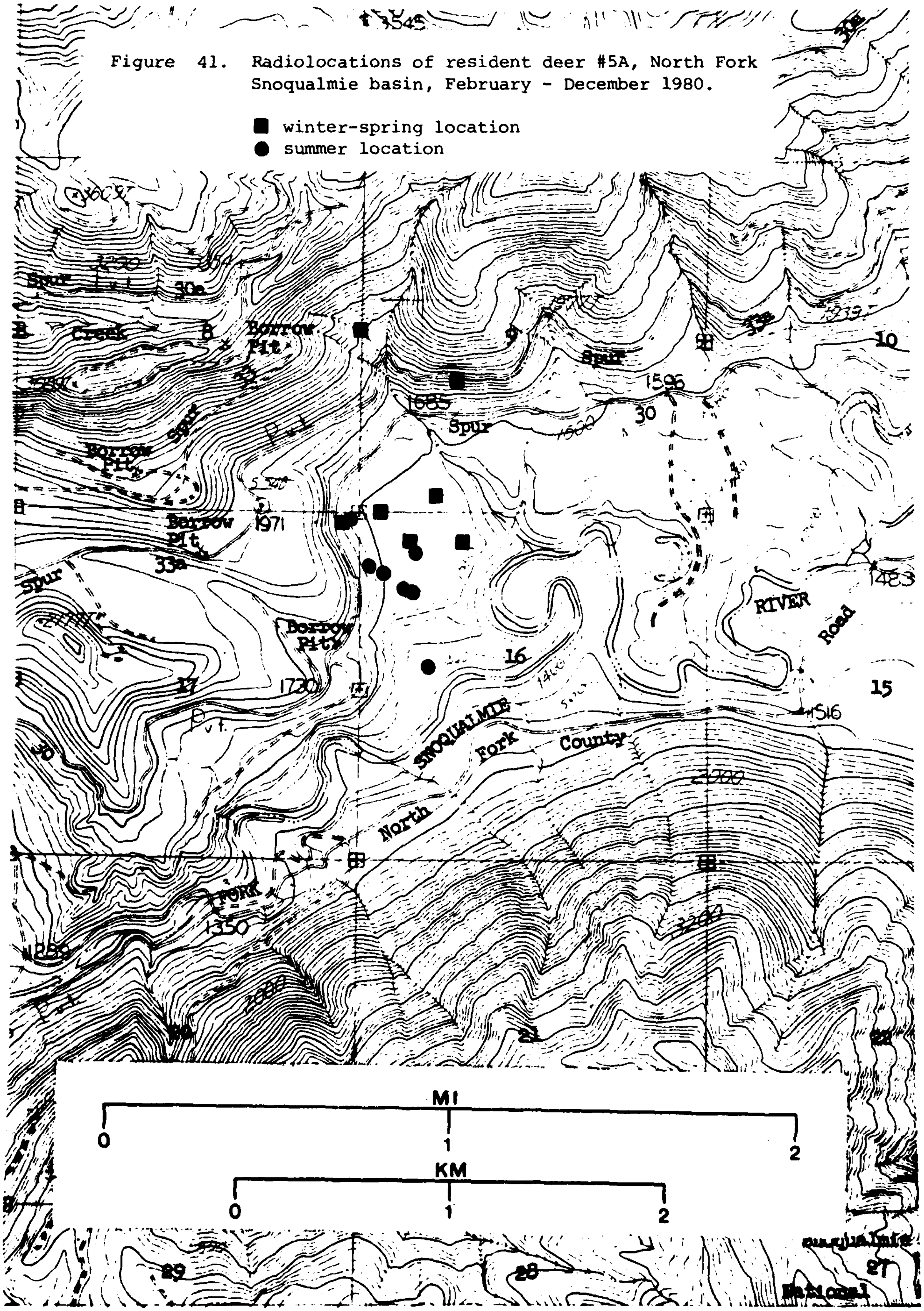
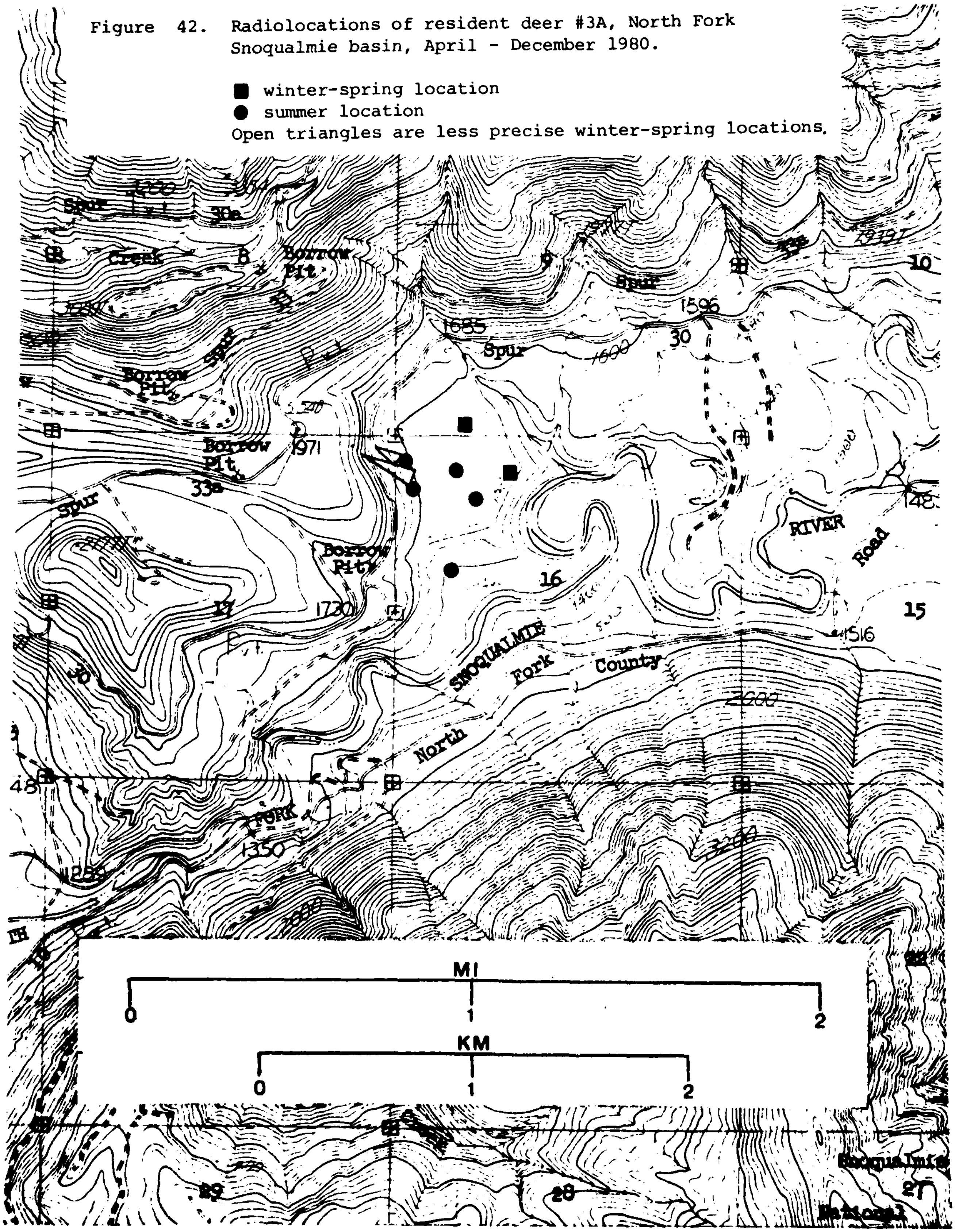


Figure 42. Radiolocations of resident deer #3A, North Fork Snoqualmie basin, April - December 1980.

■ winter-spring location
● summer location
Open triangles are less precise winter-spring locations.



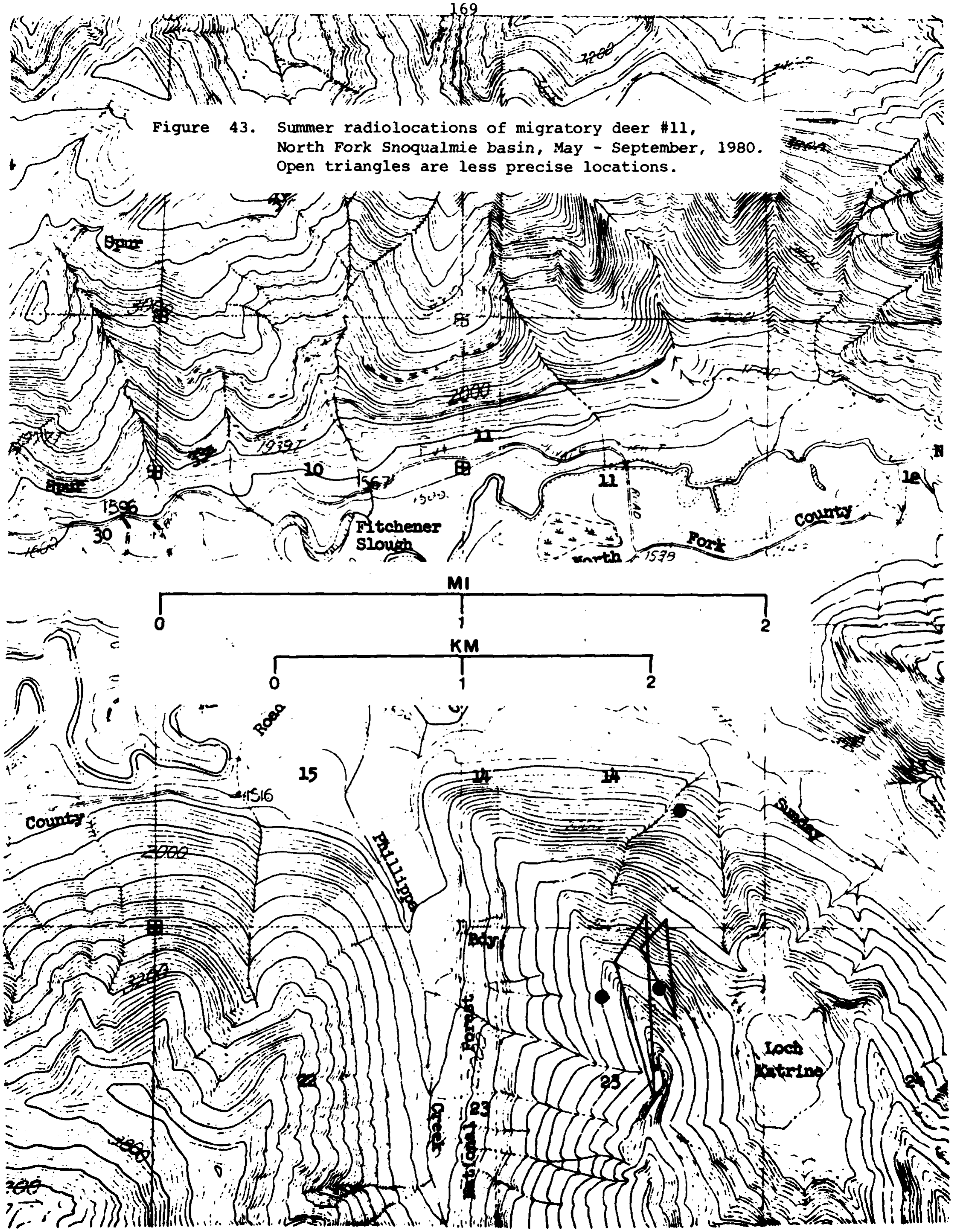



Figure 43. Summer radiolocations of migratory deer #11, North Fork Snoqualmie basin, May - September, 1980. Open triangles are less precise locations.

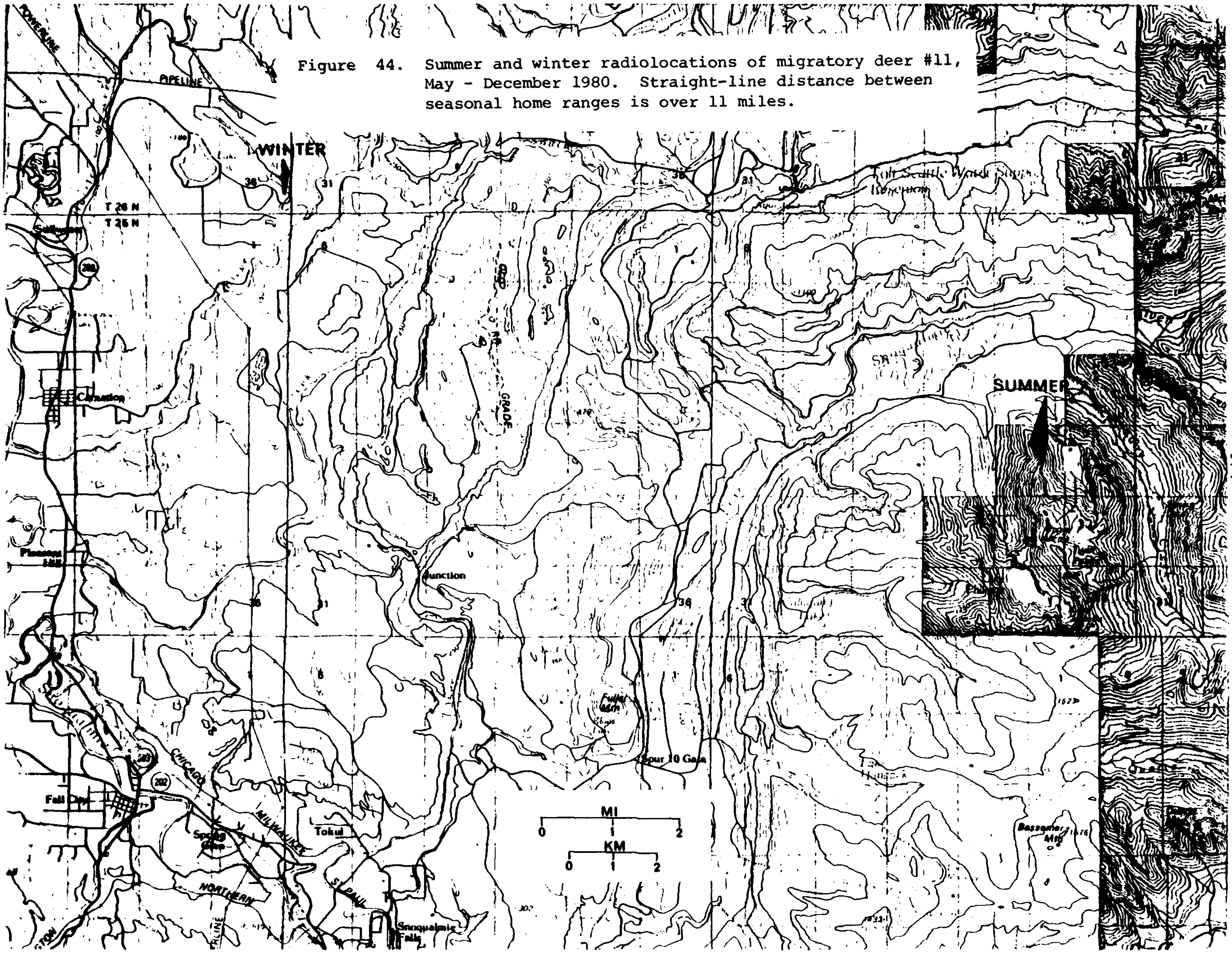
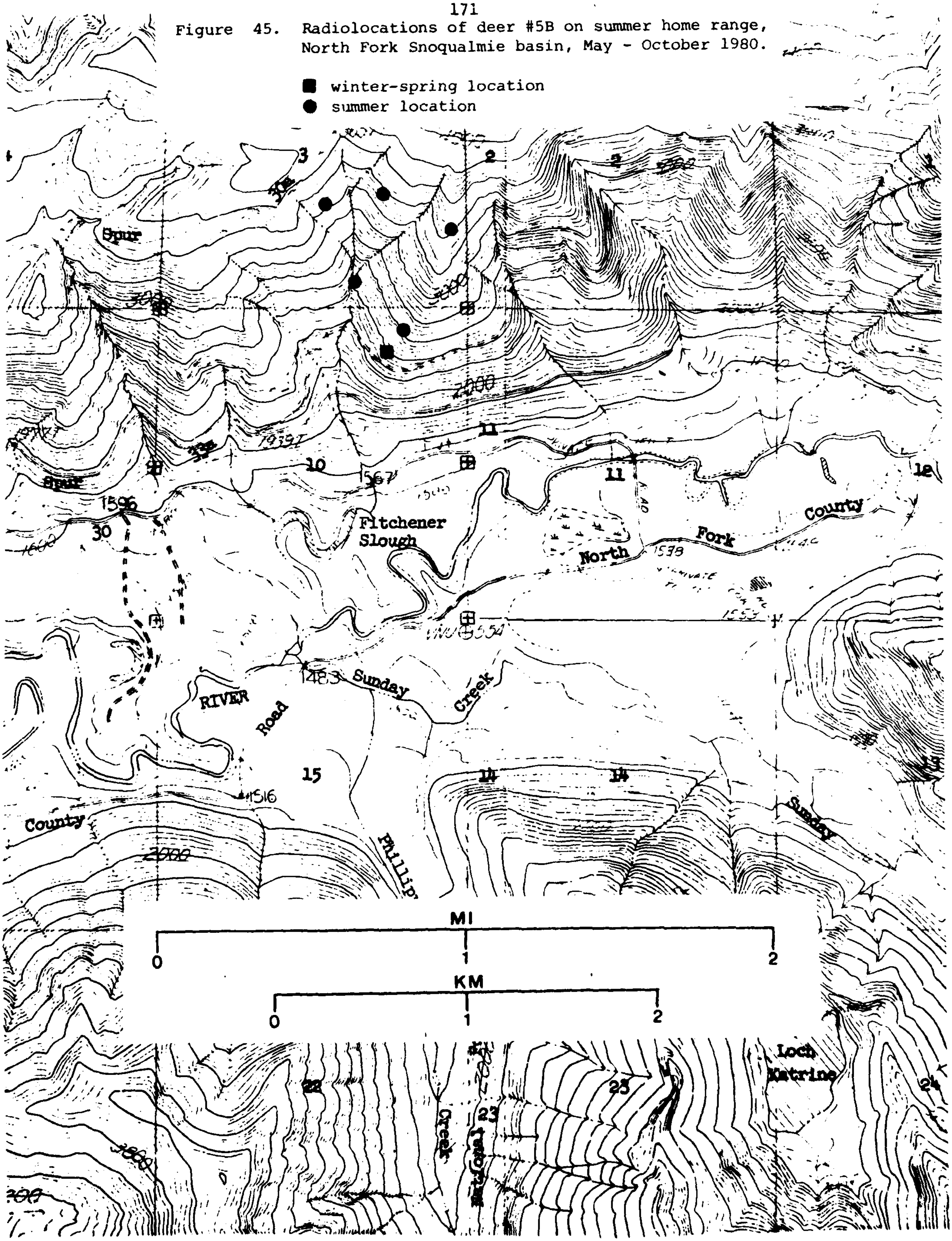



Figure 44. Summer and winter radiolocations of migratory deer #11, May - December 1980. Straight-line distance between seasonal home ranges is over 11 miles.

Figure 45. Radiolocations of deer #5B on summer home range, North Fork Snoqualmie basin, May - October 1980.



upslope to summer ranges (Figs. 46-49). None of these animals migrated to a different watershed, although two deer moved up tributary valleys.

Timing of seasonal movements and length of stay on seasonal home ranges differed markedly among our migratory animals. Based on admittedly few radiolocations, deer #7A appeared to use her summer range for, at most, three months (July-September) (Fig. 46). Deer #6, on the other hand, occupied her summer range for six months (June-November) (Fig. 47). Deer #4 made at least two visits to her winter range during summer (Fig. 48), and deer #3B's seasonal movement pattern is unclear. As of the end of December, she still appeared to be on her summer range (Fig. 49).

Harestad (1979) found that dates of seasonal home range occupancy by deer corresponded to local climatic conditions. In particular, deer summering at high elevations, where snow fell earlier, moved to their winter home ranges sooner than deer summering at middle and low elevations. Snowfalls of 12 cm (5 in) or more appeared to initiate winter migration.

Our data indicate that factors other than snow trigger migration, at least in some deer. Two deer, #7A and #11 (Figs. 46 and 44) migrated at least three weeks, and possibly as much as eight weeks, before any snow fell in the North Fork Snoqualmie drainage. If our missing deer, #5B, also migrated, she did so at least two weeks before the first snow. In contrast, deer #6 (Fig. 47) did not leave her summer range until after at least two heavy snowfalls (and snowmelts). Obviously, something other than snow stimulated some of these deer to migrate.

Harestad (1979) implied that factors which stimulate winter migration in deer may relate to migration distance. Snowfall is implicated as the trigger for migration, where distances between summer and winter home ranges are short. Over longer distances, the benefit of leaving the summer range before travel becomes difficult (and risky) may outweigh the cost of not staying where the supply of food is best.

These hypotheses are consistent with the behavior of our radiocollared migratory deer. The two deer which we know left their summer ranges early, migrated much farther than the animal which moved to its winter range only after successive heavy snows. However, there are other possible explanations for early winter migration, as well. For example, as the season progresses, food supply on the summer home range could drop below that available on the winter range. Deer would then benefit by moving to their winter home ranges. Or, deer which migrate to their winter home ranges early, may obtain a competitive edge over later arrivals by dominating access to good forage sites. These ideas are purely conjecture, but nevertheless worth considering.

We have just enough location data on radiocollared deer to suggest a couple of general habitat use patterns. First, seasonal locations of

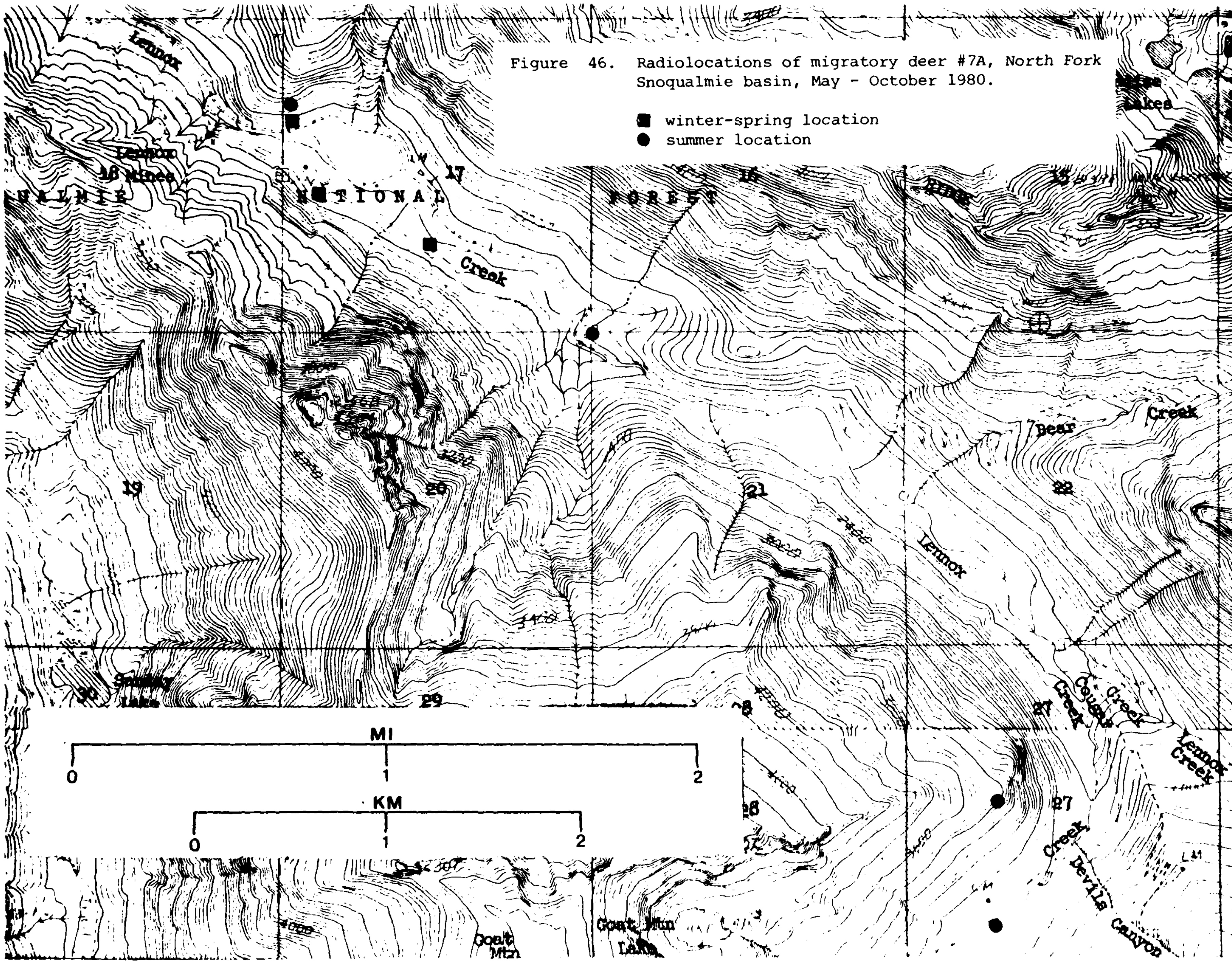



Figure 46. Radiolocations of migratory deer #7A, North Fork Snoqualmie basin, May - October 1980.

AD-A111 745 WASHINGTON STATE DEPT OF GAME OLYMPIA F/G 6/3
NORTH FORK SNOQUALMIE RIVER BASIN WILDLIFE STUDY.(U)
MAR 81 S J SWEENEY, K W KURKO, T C JUELSON DACW67-79-C-0050

UNCLASSIFIED NL

3 OF 4
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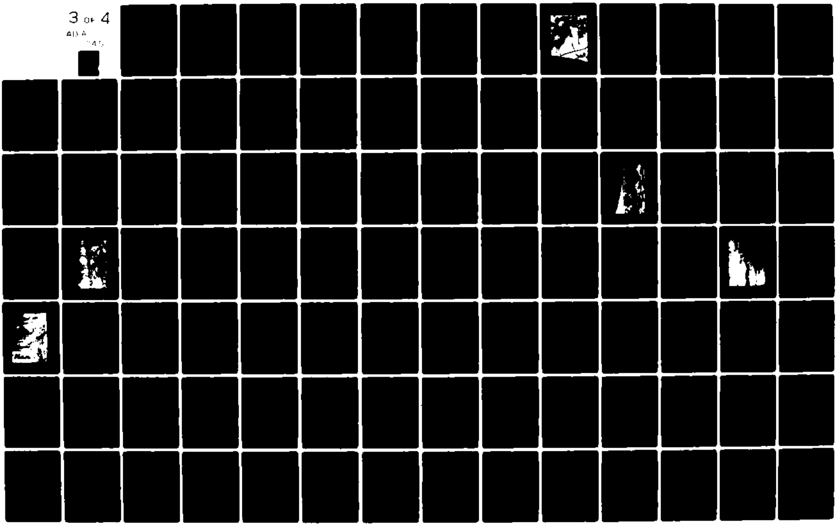

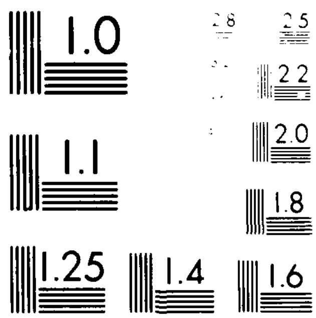
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1.25
1.4
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1.8
2.0
2.2
2.5
2.8

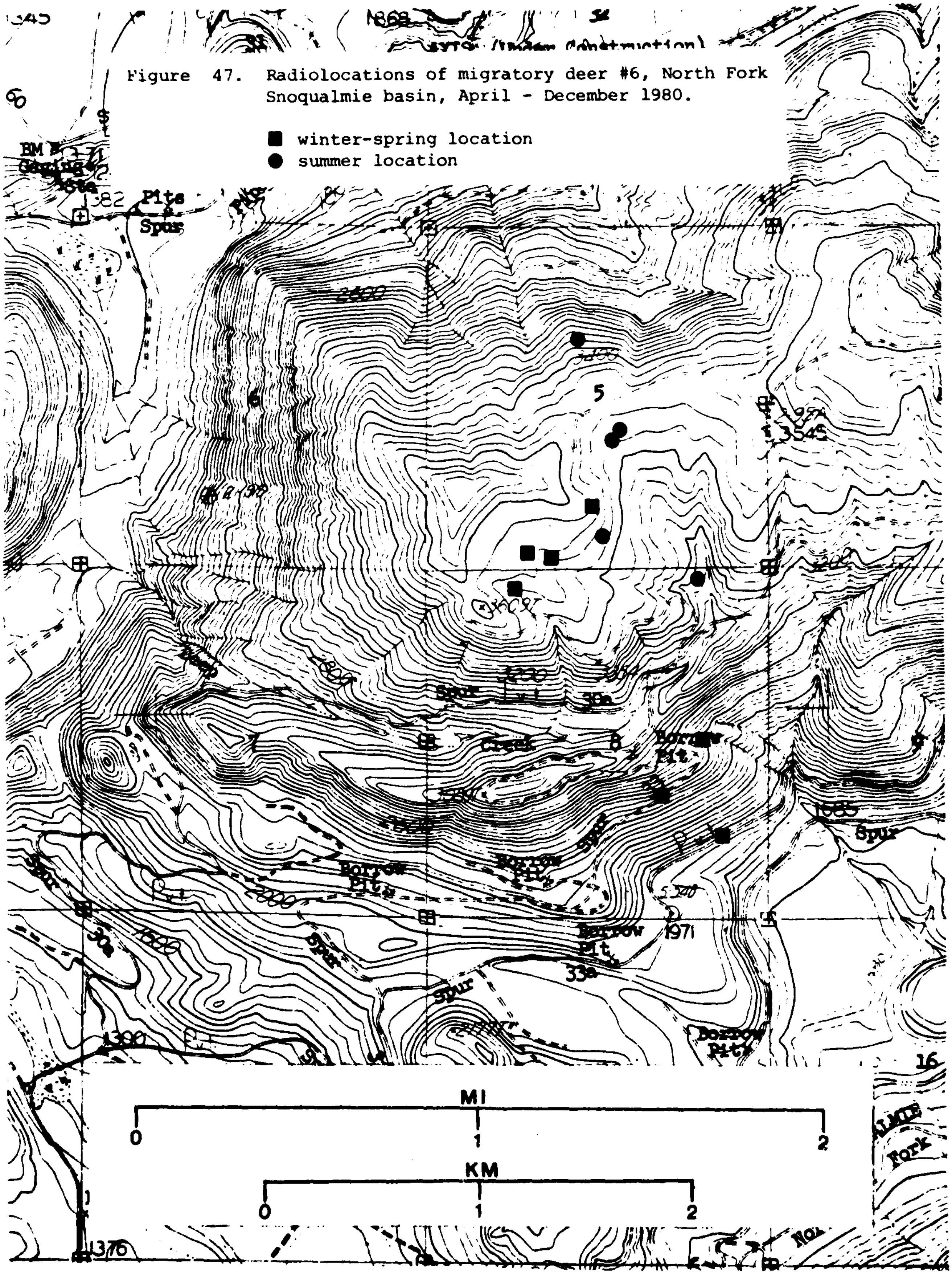



Figure 47. Radiolocations of migratory deer #6, North Fork Snoqualmie basin, April - December 1980.

■ winter-spring location
● summer location

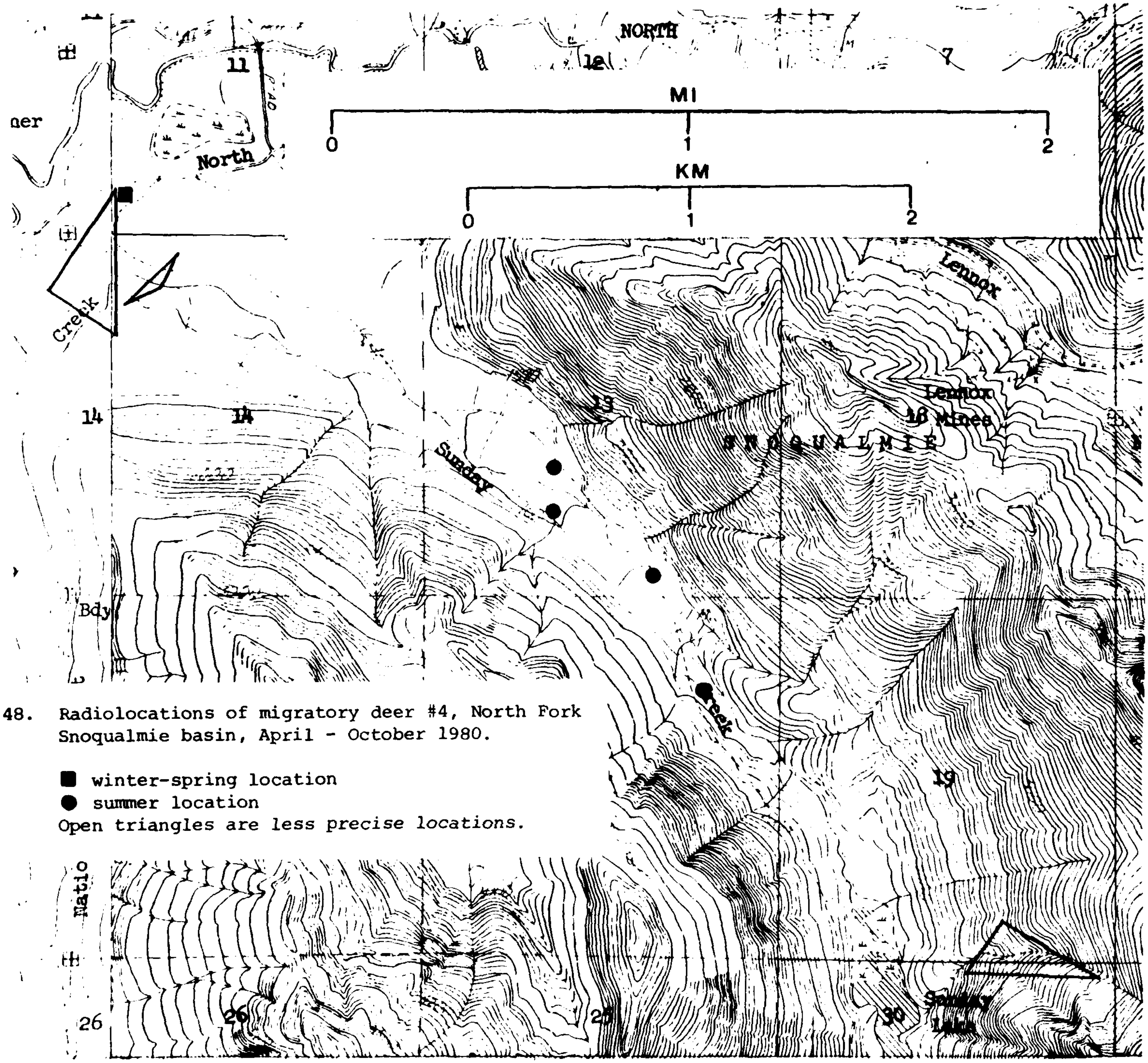
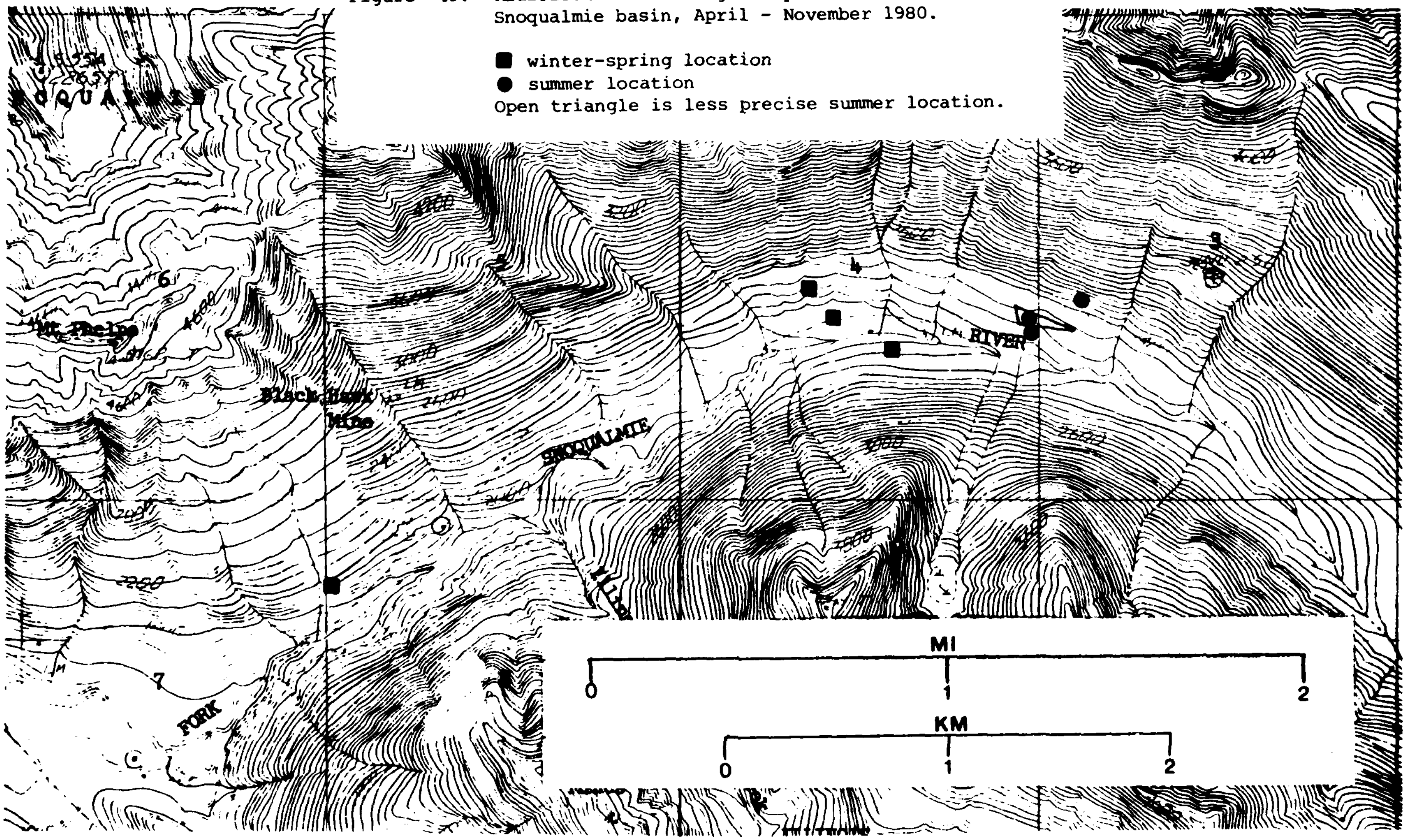



Figure 48. Radiolocations of migratory deer #4, North Fork Snoqualmie basin, April - October 1980.

■ winter-spring location
● summer location
Open triangles are less precise locations.

Figure 49. Radiolocations of migratory deer #3B, North Fork Snoqualmie basin, April - November 1980.

■ winter-spring location
● summer location
Open triangle is less precise summer location.



all animals were in, or near, both open canopy (early successional) and closed canopy forest. Old growth provided closed canopy forest for half the deer. The rest of the deer had no access to old growth, and instead used pole stage forest.

Seasonally, the two groups of deer displayed a similar pattern of daytime habitat use (Table 31). During the winter-spring period, we located them considerably more often in old growth (or pole stage) forest, than in early successional forest. In summer, the reverse was true, although less so for old growth. Regrettably, we know little about the deers' activities in these habitat types, nor do we know where they go or what they do at night.

On northern Vancouver Island, black-tailed deer exhibited a different pattern of seasonal habitat use (Harestad 1979). During spring, the majority of daytime locations of radiocollared deer were in cutover forest (up to 27 years old). In summer and winter, however, there were far more daytime deer locations in old growth forest than in cutovers. At night, deer used cutover areas more frequently than old growth, in all seasons but winter.

Apparent differences between seasonal habitat use of our deer, and those on Vancouver Island (Harestad 1979), may be partly artificial. Harestad separated his data into winter, spring, and summer locations. In contrast, we combined our winter and spring locations, because we had so few of them. If winter and spring habitat uses differ in our area, as on Vancouver Island, then combining locations for these two seasons may be misleading.

It is also likely that real differences in seasonal patterns of habitat use exist between our deer and those on northern Vancouver Island. Such differences may result from different climates, and from different proportions and types of habitat in the two study areas. Habitat selection by black-tailed deer in western Washington needs much more study.

To summarize our findings, the proposed reservoir area supports an unusually high density of black-tailed deer in winter and early spring. Some of these animals (migrators) move to adjoining slopes or tributary valleys to their summer ranges, while others (residents) remain in the project area year round. Still other deer summer in or adjacent to the project area, but winter at lower elevations, frequently outside the North Fork Snoqualmie river drainage. Habitat diversity is the probable key to the tremendous density of deer in the project area. Though this habitat diversity will likely decline as early seral stages of logged forest mature, it should remain higher than in most other areas, due to natural diversity created by the many wetlands. Thus, the project area should remain productive deer habitat at all stages of the forest cutting cycle.

Table 31. Locations of radiocollared deer, by season and habitat type, North Fork Snoqualmie basin, 1980.

| | Winter-Spring | | | Summer | | |
|---|---|---|---|---|---|---|
| Deer | Early successional forest | Old growth forest | Other | Early successional forest | Old growth forest | Unknown |
| 3B | | 3 | 1 | 2 | 1 | 1 |
| 4 | 1 | | | 3 | 2 | 2 |
| 7A | 1 | 2 | | 1 | 3 | |
| 11 | -- | -- | -- | 3 | | 2 |
| Total | 2 (25%) | 5 (63%) | 1 (12%) | 9 (45%) | 6 (30%) | 5 (25%) |

| Deer | Early successional forest | Pole stage forest | Unknown | Early successional forest | Pole stage forest |
|---|---|---|---|---|---|
| 3A | 1 | 2 | 1 | 5 | |
| 5A | 3 | 4 | | 6 | 1 |
| 5B | -- | -- | -- | 4 | 2 |
| 6 | 1 | 6 | | 4 | 1 |
| Total | 5 (28%) | 12 (67%) | 1 (5%) | 19 (83%) | 4 (17%) |

Other Large Mammals. Population estimates of mountain goats in the North Fork Snoqualmie drainage (Table 32) were provided by two persons who have spent many years watching and hunting mountain goats in the vicinity of the proposed project. Because our own counts of goats on Little Mt. Phelps are similar to their figures, we believe their information is reliable. Based on these figures, an estimate of 54 mountain goats in the drainage appears reasonable.

The number of mountain goats actually living adjacent to, or entering the proposed reservoir site itself, is unknown. However, on 14 April 1979 we observered 23 mountain goats on lower elevation slopes and cliffs directly above the proposed reservoir. John Cook (pers. commun., Olympic Taxidermy, Renton, Wash.) has photographed mountain goats crossing the USFS road near the upstream end of the proposed reservoir. Furthermore, both he and Larry Kerr (pers. commun., Weyerhaeuser Co., Snoqualmie, Wash.) state that goats have been seen on the valley floor near Phelps Campground. Sightings of mountain goats within the proposed reservoir boundary may represent seasonal migration, or dispersal, across the basin.

We obtained little direct information on black bear abundance in the North Fork Snoqualmie basin. Between 1976 and 1978, projected yearly bear harvest per square mile in the Snoqualmie Game Management Unit was in the top 10 percent of the 66 game management units in western Washington (WDG 1979). This finding suggests a relatively dense bear population for the Snoqualmie unit, as a whole. However, Regional Game Biologist Douglas Bellingham (pers. commun., WDG, Seattle, Wash.) states that most of these animals are killed in forested swampy areas at lower elevation. During the two years we spent in the study area, we saw only two black bears (Photo 33). Larry Kerr (pers. commun., Weyerhaeuser Co., Snoqualmie, Wash.) maintains that bear numbers in the basin are still very low, following several large spring bear harvests in response to tree damage complaints.

To obtain reliable estimates of bobcat and cougar numbers in the proposed project area would take several years of field study. Two hound-hunters who regularly hunt bobcats in the basin, told us they consider bobcats abundant within the proposed reservoir boundary, particularly during late winter. These individuals were concerned that a reservoir would flood habitat critical to wintering "cats". Cougars appear to be uncommon in the basin, because these hunters had never seen their tracks there. However, we do have one reliable report of a cougar sighting in August 1978, just below the confluence of Sunday Creek and the North Fork Snoqualmie River (pers. commun., John Cook, Olympic Taxidermy, Renton, Wash.).

Results of our coyote scent station transect (an average of 9 of 30 stations visited per night) indicated only that coyote densities in the project area are apparently greater than average densities in the western United States. Statistical limitations of the sampling method pre-

Table 32. Estimated numbers* of mountain goats in North Fork Snoqualmie drainage.

| | JC | GH |
|---|---|---|
| Little Mt. Phelps (Mt. Phelps on USGS maps) | 16-19 | 12-18 |
| Upper Lennox Creek - Cougar Lake | | 10 |
| Goat Mountain Lake | 5 | |
| Ridge between Lennox and Sunday Creeks | 9 | 10-12 |
| Twin Peaks - Philippa Lake | 9 | 12-24 |
| Bessemer Mountain | 13 | |
| Total | 52-55 | 44-64 |

*Estimates provided by John Cook (Olympic Taxidermy, Renton, Wash.) and George Hadaller (Seattle, Wash.).

Photo 33. Black bear in regenerating conifer forest near the proposed reservoir site.

vent more detailed analysis (pers. commun., Robert Roughton, FWS, Logan, Utah).

## Bird Studies

### Non-game Birds

Censuses of non-game birds in the project area enabled us to estimate densities of the more common species in several habitat types (Tables 33-36). Appendices F and G show derivations of these estimates. Birds observed too seldom to calculate densities are listed in Appendix A.

Results of our non-game bird censuses during 1979 (Tables 33-35) indicated that the season of highest bird density varied with habitat type. In open communities (Early Successional Forest and Marsh/Swamp), total bird densities were highest during summer. In closed canopy communities (Pole Stage, Mixed, and Mature/Old Growth forests), highest bird densities occurred during spring or fall migration. Although we did not census birds in winter, our field observations show relatively few birds in the basin at that time.

In 1980, we censused birds in previously unsampled habitat types, but only during summer (Table 36). A precise comparison of bird densities among all habitat types studied is impractical, because census data were collected in different years, by different observers, on routes of unequal sample size (see Appendices F and G, and Methods p. 144). Nevertheless, Tables 33-36 substantiate predicted patterns of habitat use by a few bird groups. As expected, highest breeding densities of woodpeckers were observed in old growth forest and wetland communities, where snags used for nesting and feeding are numerous. Small, insect-gleaning birds, such as chickadees, kinglets, and warblers, were generally most abundant in closed canopy forest communities. Such forests, with their height and structure, may offer these birds more habitat in which to nest and feed, than do open habitats. In contrast, ground and shrub-foragers, like rufous-sided towhees, dark-eyed juncos, and sparrows, were usually more numerous in open forest communities and wetlands, where plants seasonally produce large crops of easily accessible seeds and berries.

As with small mammals, we extrapolated our summer bird census data for 1979 and 1980, to obtain a rough estimate of the total number of non-game birds within the proposed reservoir boundary (Table 37). The result indicates that breeding habitats of over 3,200 non-game birds would be inundated if the reservoir were built. Of course, numbers of non-game birds, like those of other animals in the project area, change with seasons and plant succession. We lack data to quantify these changes, particularly for future conditions. Therefore, we use our single population estimate of non-game birds to approximate the average,

Table 33. Estimated densities (birds/ha)* of common non-game birds in four habitat types, North Fork Snoqualmie basin, May 1979.

| Species | Early Successional Forest | Pole Stage Coniferous Forest | Mixed Forest | Old Growth Coniferous Forest |
|---|---|---|---|---|
| Rufous Hummingbird | 1.41 | 0.57 | 0.57 | 1.99 |
| Common Flicker | 0.02 | | | 0.02 |
| Pileated Woodpecker | | 0.01 | 0.01 | 0.01 |
| Hairy Woodpecker | | | | 0.10 |
| Willow Flycatcher | 0.06 | | | |
| Western Flycatcher | | 0.23 | 0.59 | 1.11 |
| Steller's Jay | 0.03 | 0.09 | 0.06 | 0.08 |
| Common Crow | + | + | 0.01 | |
| Black-capped Chickadee | | + | | |
| Chestnut-backed Chickadee | | 0.51 | 0.76 | 0.88 |
| Winter Wren | | 0.36 | 0.77 | 1.60 |
| American Robin | 0.14 | 0.08 | 0.13 | 0.04 |
| Varied Thrush | | 0.16 | 0.08 | 0.12 |
| Hermit Thrush | | 0.13 | | |
| Swainson's Thrush | | 0.09 | | 0.02 |
| Golden-crowned Kinglet | | 1.14 | 1.14 | 2.66 |
| Hutton's Vireo | | 0.18 | 0.46 | |
| Warbling Vireo | | | 0.02 | |
| Orange-crowned Warbler | 0.14 | 0.70 | 0.56 | |
| Yellow-rumped Warbler | | 0.76 | 1.76 | |
| Townsend's Warbler | | 0.90 | 1.28 | 1.60 |
| MacGillivray's Warbler | 0.26 | 0.10 | 0.04 | |
| Common Yellowthroat | + | | 0.07 | |
| Wilson's Warbler | 0.02 | 0.54 | 0.30 | 0.72 |
| Red-winged Blackbird | | | | |
| Rufous-sided Towhee | | | | |
| Dark-eyed Junco | 0.52 | 0.23 | 0.09 | |
| White-crowned Sparrow | 0.20 | | | |
| Song Sparrow | 0.12 | | 0.22 | 0.04 |
| Total | 2.92 | 6.78 | 8.92 | 10.99 |

*A "+" means that bird was observed outside of detection distance.

Table 34. Estimated densities (birds/ha)* of common non-game birds in five habitat types, North Fork Snoqualmie basin, June 1979.

| Species | Early Successional Forest | Pole Stage Coniferous Forest | Mixed Forest | Old Growth Coniferous Forest | Marsh/ Swamp |
|---|---|---|---|---|---|
| Rufous Hummingbird | | 0.28 | | + | |
| Common Flicker | + | | | | |
| Pileated Woodpecker | | | + | 0.02 | |
| Hairy Woodpecker | | 0.01 | | 0.03 | 0.06 |
| Willow Flycatcher | 1.14 | 0.36 | | | 0.60 |
| Western Flycatcher | | 0.55 | 0.77 | 1.80 | 0.07 |
| Steller's Jay | 0.01 | 0.06 | 0.06 | 0.06 | 0.04 |
| Common Crow | + | + | 0.05 | | 0.01 |
| Black-capped Chickadee | | | | | 0.28 |
| Chestnut-backed Chickadee | | 0.38 | 0.63 | 0.83 | + |
| Winter Wren | + | 0.77 | 0.50 | 1.20 | 0.04 |
| American Robin | 0.06 | 0.08 | 0.07 | 0.08 | 0.02 |
| Varied Thrush | 0.06 | 0.40 | 0.17 | + | 0.01 |
| Hermit Thrush | | 0.03 | | | |
| Swainson's Thrush | 0.11 | 0.40 | 0.32 | 0.68 | 0.14 |
| Golden-crowned Kinglet | | 1.26 | 0.63 | 3.34 | |
| Hutton's Vireo | | | + | | |
| Warbling Vireo | | | 0.06 | | |
| Orange-crowned Warbler | 0.28 | 0.88 | + | | 0.16 |
| Yellow-rumped Warbler | | 0.26 | 0.26 | | |
| Townsend's Warbler | | 0.36 | 0.46 | 0.14 | + |
| MacGillivray's Warbler | 0.76 | 0.10 | 0.10 | | 0.64 |
| Comm Yellowthroat | | | 0.07 | | 1.74 |
| Wilson's Warbler | 0.04 | 0.22 | 0.44 | 0.52 | 0.02 |
| Red-winged Blackbird | | | | | 0.29 |
| Rufous-sided Towhee | 0.50 | 0.03 | | | |
| Dark-eyed Junco | 0.06 | 0.50 | 0.14 | | |
| White-crowned Sparrow | 0.34 | | | | |
| Song Sparrow | 0.58 | 0.10 | 0.20 | 0.04 | 0.64 |
| Total | 3.94 | 7.03 | 4.93 | 8.74 | 4.76 |

*A "+" means that bird was observed outside of detection distance.

Table 35. Estimated densities (birds/ha)* of common non-game birds in five habitat types, North Fork Snoqualmie basin, September 1979.

| Species | Early Successional Forest | Pole Stage Coniferous Forest | Mixed Forest | Old Growth Coniferous Forest | Marsh/ Swamp |
|---|---|---|---|---|---|
| Rufous Hummingbird | | | | | |
| Common Flicker | | 0.03 | | 0.01 | + |
| Pileated Woodpecker | | 0.01 | + | | 0.01 |
| Hairy Woodpecker | | | 0.02 | 0.03 | 0.02 |
| Willow Flycatcher | | | | | |
| Western Flycatcher | | | | | |
| Steller's Jay | 0.04 | 0.05 | 0.10 | 0.15 | 0.09 |
| Common Crow | + | 0.01 | 0.03 | | + |
| Black-capped Chickadee | 1.02 | 0.25 | | | |
| Chestnut-backed Chickadee | | 1.01 | 2.53 | 2.92 | + |
| Winter Wren | | 0.77 | 0.18 | 1.12 | |
| American Robin | 0.04 | 0.20 | 0.02 | 0.09 | 0.08 |
| Varied Thrush | | 0.24 | 0.19 | 0.11 | 0.01 |
| Hermit Thrush | | 0.19 | 0.03 | | |
| Swainson's Thrush | | 0.01 | | | |
| Golden-crowned Kinglet | 0.13 | 7.70 | 2.40 | 4.17 | 0.57 |
| Hutton's Vireo | | | | | |
| Warbling Vireo | | | | | |
| Orange-crowned Warbler | | | | | 0.02 |
| Yellow-rumped Warbler | 0.25 | | | | |
| Townsend's Warbler | | 0.05 | | | |
| MacGillivray's Warbler | | | | | |
| Common Yellowthroat | | | | | 1.16 |
| Wilson's Warbler | | | | | |
| Red-winged Blackbird | | | | | 0.02 |
| Rufous-sided Towhee | 0.06 | 0.09 | | | 0.04 |
| Dark-eyed Junco | 1.49 | 0.55 | 0.05 | 0.37 | 0.29 |
| White-crowned Sparrow | 0.14 | | | | |
| Song Sparrow | 0.29 | 0.06 | 0.03 | 0.04 | 0.46 |
| Total | 3.46 | 11.22 | 5.58 | 9.01 | 2.77 |

*A "+" means that bird was observed outside of detection distance.

Table 36. Estimated densities (birds/ha)* of common non-game birds in three habitat types, North Fork Snoqualmie basin, June-July 1980.

| Species | Early Successional Forest/Marsh | Broadleaf Forest | Bog |
|---|---|---|---|
| Rufous Hummingbird | 1.57 | | |
| Common Flicker | 0.02 | | 0.04 |
| Pileated Woodpecker | | | 0.05 |
| Hairy Woodpecker | 0.06 | | 0.14 |
| Willow Flycatcher | 1.34 | | + |
| Western Flycatcher | | 0.42 | 0.45 |
| Steller's Jay | 0.04 | | 0.14 |
| Common Crow | + | | 0.03 |
| Black-capped Chickadee | + | 0.47 | |
| Chestnut-backed Chickadee | | | |
| Winter Wren | 0.08 | + | 0.20 |
| American Robin | 0.04 | | 0.06 |
| Varied Thrush | | 0.04 | |
| Hermit Thrush | | | |
| Swainson's Thrush | 0.44 | 0.53 | 0.07 |
| Golden-crowned Kinglet | | | |
| Hutton's Vireo | | 0.34 | |
| Warbling Vireo | 0.02 | 0.84 | |
| Orange-crowned Warbler | 0.34 | 0.12 | 0.02 |
| Yellow-rumped Warbler | 0.56 | | |
| Townsend's Warbler | | | |
| MacGillivray's Warbler | 0.70 | 0.34 | 0.06 |
| Common Yellowthroat | 2.16 | | 1.84 |
| Wilson's Warbler | 0.02 | 0.46 | 0.04 |
| Red-winged Blackbird | | | |
| Rufous-sided Towhee | 0.18 | | |
| Dark-eyed Junco | 1.30 | 0.17 | + |
| White-crowned Sparrow | | | |
| Song Sparrow | 0.28 | 0.22 | 0.80 |
| Total | 9.15 | 3.95 | 3.94 |

*A "+" means that bird was observed outside of detection distance.

Table 37. Rough estimate of number of common non-game birds breeding within proposed reservoir boundary, North Fork Snoqualmie basin, June 1979, and June-July 1980.

| Habitat type | Hectares | Birds per Hectare | Total Birds |
|---|---|---|---|
| Marsh/Swamp | 52.8 | 4.76 | 251.3 |
| Bog | 4.7 | 3.94 | 18.5 |
| Pond* | 17.2 | 4.76 | 81.9 |
| River/Stream** | 91.3 | - | - |
| Early Successional Forest/Marsh | 35.1 | 9.15 | 321.2 |
| Early Successional Forest | 118.3 | 3.94 | 466.1 |
| Pole Stage Coniferous Forest | 195.8 | 7.03 | 1,376.5 |
| Mature/Old Growth Coniferous Forest | 21.3 | 8.74 | 186.2 |
| Broadleaf Forest | 31.2 | 3.95 | 123.2 |
| Mixed Forest | 89.7 | 4.93 | 442.2 |
| Sand Slide** | 3.1 | - | - |
| Logging Road** | 11.5 | - | - |
| Total | 672.0 | | 3,267.1 |

*The density figure for Pond is taken from that of Marsh/Swamp, because the Marsh/Swamp census included many ponds.

**Habitat type not sampled.

baseline condition in the project area. Impact of the proposed project on non-game birds can then be quantified, by comparing baseline (without project) conditions, to conditions expected to occur with the project.

Game Birds

Grouse. In 44 listening stops during our spring 1979 grouse census, we heard 34 blue grouse and 1 ruffed grouse. We used the following formula to estimate number of adult male blue grouse ($G$) within the boundary of the proposed reservoir.

$$G = n \times \frac{A}{a}$$

where $n$, number of grouse heard = 34

$A$, acreage of proposed reservoir = 1,660

$a$, total hearing acreage of plots = 1,366.25

This calculation resulted in an estimate of 41 male blue grouse within the project area. Assuming an even sex ratio, there would be 2 x 41 = 82 adult blue grouse within the proposed reservoir zone. After their broods have hatched, blue grouse would obviously be much more numerous.

We did not estimate ruffed grouse numbers on the study area. Our count of only one ruffed grouse during the census would have given a very low figure (about 10 grouse), when projected to the entire reservoir area. Based on our general field observations, we believe there are considerably more than 10 ruffed grouse within the proposed reservoir boundary. We are unsure why we had such a low count, but grouse drumming activity may have peaked before we began field studies (pers. commun., Leo Salo, WDG, Seattle, Wash.). Nevertheless, our field observations suggest that ruffed grouse are generally less abundant than blue grouse within the basin. Instead, ruffed grouse seem more common than "blues" below Wagner bridge, where the forest is older and takes on a more mixed coniferous - broadleaf character.

Waterfowl. Table 38 is a compilation of our waterfowl observations in the basin. These data are useful for estimating relative abundances of waterfowl, and revealing their general patterns of habitat use.

Mallards appear to be the most abundant waterfowl in the basin. They are also the most diverse in their habitat use, having been observed on rivers and streams, ponds, and in other habitat types, such as Early Successional Forest/Marsh. Other species were restricted either to ponds, or to running waters.

Of ducks observed exclusively on ponds in the basin, the most common were wood duck, hooded merganser, ring-necked duck, and green-winged teal. Ring-necked ducks may not be as common as suggested by our

Table 38. Waterfowl observations by habitat type, North Fork Snoqualmie basin, December 1978 - November 1979.

| Species | Ponds | River | Other* | Total |
|---|---|---|---|---|
| Swan | 1 | | | 1 |
| Mallard | 21 | 4 | 2 | 27 |
| Pintail | 1 | | | 1 |
| Green-winged Teal | 8 | | | 8 |
| Wood Duck | 12 | | | 12 |
| Ring-necked Duck | 9 | | | 9 |
| Common Goldeneye | 3 | | | 3 |
| Goldeneye sp. | 1 | | | 1 |
| Harlequin Duck | | 6 | | 6 |
| Hooded Merganser | 11 | | | 11 |
| Common Merganser | | 8 | | 8 |

*Includes Early Successional Forest/Marsh and undetermined habitat types over which bird was flying.

data, because we think we saw the same pair several times. We know that all the above species, except for ring-necked duck, breed within the proposed reservoir boundary, as we have seen ducklings with adult birds. We are unsure whether ring-necks breed in the study area, although we saw at least one adult pair several times early in the breeding season. The possibility that ring-necked ducks do breed in the basin is of interest, because there are very few breeding records of this species in western Washington.

The only two ducks seen exclusively on rivers and streams were harlequin ducks and common mergansers. We know harlequins breed on the North Fork Snoqualmie River, because we observed a female with six downy young, just below Spur 10 bridge. We are not sure whether common mergansers breed on the river, although observations of adults during spring and summer suggest they do.

We observed common mergansers along the entire river, while we saw harlequins only below Wagner bridge. If these differences are real, they may relate to different feeding habits of the two species. Harlequin ducks forage for aquatic insects, while common mergansers are primarily fish eaters. Generally speaking, the lower river contains better aquatic insect habitat (firmer, more cobbly substrates) than the upper river. Thus, it may be more suited to harlequins. Availability or size of fishes, on the other hand, may follow a different pattern, so that common mergansers are distributed differently.

Band-tailed Pigeon. We know little about total numbers of band-tailed pigeons in the area of the proposed project. Density estimates obtained during non-game bird censuses (Appendix F) probably underestimate actual band-tailed pigeon densities, as only unmated males vocalize (pers. commun., Douglas Bellingham, WDG, Seattle, Wash.). During September, just prior to their southward migration, we have observed large flocks of up to 150 band-tails on slopes and ridges above the basin bottom. There, they gather to roost and feed on abundant huckleberries, perhaps acquiring fat reserves for their journey south.

## Raptors

We have compiled our miscellaneous observations of raptors in the study area, according to season (Table 39) and habitat type (Table 40). Seasonal comparisons are unfortunately biased because we had more field time during summer and fall, than in winter and spring. We did find active nests of two pairs of raptors--American kestrel and golden eagle--in the basin. The kestrel nest was in a hollow snag within the proposed inundation zone. The discovery of the golden eagle nest was especially exciting, because there are only 10 known nesting pairs of this species in western Washington (pers. commun., Richard Knight, WDG, Olympia, Wash.). This particular pair of golden eagles is further distinguished as the only cliff-nesting pair in western Washington. All other known western Washington golden eagle nests are in trees, although cliffs are their usual nesting habitat in eastern Washington. From 12

Table 39. Raptor observations by season, North Fork Snoqualmie basin, December 1978 - November 1979.

| Species | Dec - Feb | Mar - Apr | May - Aug | Sept - Nov | Total |
|---|---|---|---|---|---|
| Goshawk* | | 1 | | | 1 |
| Sharp-shinned Hawk | | | 4 | 1 | 5 |
| Cooper's Hawk | | 1 | 2 | 9 | 12 |
| Red-tailed Hawk | 2 | 3 | 5 | 4 | 14 |
| Golden Eagle | | 2 | 2 | | 4 |
| Bald Eagle | | 2 | | 3 | 5 |
| Marsh Hawk | | 1 | | | 1 |
| Osprey | | | 1 | | 1 |
| American Kestrel | | 1 | 15 | 2 | 18 |
| Screech Owl | | 2 | 1 | | 3 |
| Pygmy Owl | | | | 4 | 4 |
| Saw-whet Owl | | 3 | | | 3 |

*This was a dead, immature bird.

Table 40. Raptor observations by habitat type, North Fork Snoqualmie basin, December 1978 - November 1979.

| Species | Pond | River | Early Successional Forest | Second Growth Forest | Old Growth Forest | Unknown | Total |
|---|---|---|---|---|---|---|---|
| Goshawk* | | | | | 1 | | 1 |
| Sharp-shinned Hawk | 1 | | | | 4 | | 5 |
| Cooper's Hawk | 1 | | 4 | 5 | | 2 | 12 |
| Red-tailed Hawk | | 2 | 2 | | 6 | 4 | 14 |
| Golden Eagle | | | 2 | | 2 | | 4 |
| Bald Eagle | | 2 | | 1 | | 2 | 5 |
| Marsh Hawk | 1 | | | | | | 1 |
| Osprey | | 1 | | | | | 1 |
| American Kestrel | | | 17 | | | 1 | 18 |
| Screech Owl | | | | 2 | | 1 | 3 |
| Pygmy Owl | | | | 1 | 2 | 1 | 4 |
| Saw-whet Owl | | | | 3 | | | 3 |

*This was a dead, immature bird.

June (the date we discovered the nest) through 16 July we spent several hours observing activities at the nest. A single youngster (one of two originally seen on the nest) apparently fledged between 16 and 22 July.

We also observed several other raptor species during the breeding season (Table 39), and located a probable sharp-shinned hawk nest. These sightings suggest that at least two species of accipiters, as well as red-tailed hawk, and at least three species of owls also nest in the basin.

Numbers of raptors observed in different habitat types (Table 40) are biased by amount of time observers spent in different habitat types, and by different visibilities of raptors among various types of cover. Nevertheless, habitat use patterns for a couple of species are apparent.

Perhaps the most noticeable pattern is the prevalence of American kestrels in Early Successional Forest. In western Washington mountains, regenerating clearcut areas are undoubtedly a preferred habitat of kestrels, because kestrels typically hunt in open areas. They are also hole-nesters, often using vacant nests of woodpeckers and other cavity-nesting birds (pers. commun., Douglas Wechsler, WDG, Seattle, Wash.). In addition to the active kestrel nest we discovered, we found a probable kestrel nest in a hollow snag on a clearcut hillside. Our many kestrel sightings in similar habitat, within and adjacent to the proposed reservoir, suggest that several kestrel nests exist in the project area.

Clearcutting may have improved conditions for American kestrels in mountains of western Washington, by creating open habitat. It may also have caused the apparent westward range extension of golden eagle nesting. On the other hand, clearcutting has reduced preferred habitats of some other species, such as spotted owl and goshawk. Our data also showed a surprising number of red-tailed hawk observations in old growth forest (Table 40). Their use of old growth may be limited to perches and nest sites, as red-tails are usually considered open area hunters.

Although we think we have observed most species of hawks using the basin, our knowledge of owls in the area is poor. We spent only two nights (one of them in a blizzard) attempting to elicit responses to tape recorded owl calls. We believe that species other than those already identified, such as great horned owl, and possibly even spotted owl (in remaining old growth stands), may exist within or use areas potentially impacted by the proposed reservoir.

## Amphibian and Reptile Studies

We did little active searching of the study area for amphibians and reptiles. Table 41 compiles our incidental sightings of these animals within the basin, with comments on where we found them, and general

Table 41. Amphibians and reptiles observed in North Fork Snoqualmie basin, during 1979 and 1980 field studies.

| Species | Habitat* |
|---|---|
| <u>Amphibians</u> | |
| Northwestern Salamander | Humid sites - open grasslands to dense forest; often beneath debris along streambanks; lays eggs on debris in ponds, lakes, slow-moving streams. Found in all beaver ponds and bogs sampled f[illegible] in North Fork Snoqualmie basin. [illegible]ly abundant in some ponds. |
| Pacific Giant Salamander | Rivers, tributaries, and surrounding cool, humid forests; breeds in river headwaters; eggs attached to submerged timber. Occasional specimens found during electroshocking of riffle areas along much of North Fork Snoqualmie River. |
| Rough-skinned Newt | Ponds, lakes, slow-moving streams with submerged vegetation, and adjacent humid forests or grasslands; lays eggs on aquatic plants of submerged twigs. Captured in fish traps at bog ponds #20 and #26, and slough #13 (Figure 12). |
| Tailed Frog | Usually clear, cold, swift-flowing mountain streams; sometimes found near water in damp forests, or in more open areas in cold, wet weather; eggs attached to downstream sides of rocks. Found in Lennox Creek during insect sampling, and upper North Fork Snoqualmie River during field exploration. |
| Western Toad | Near springs, streams, meadows, woodlands; egg strings attached to vegetation in shallow, usually still water. Found in marshes, swamps, and several adjacent habitats in North Fork Snoqualmie basin. |
| Pacific Treefrog | On ground among shrubs and grass, close to water. Captured or heard in and near most marshes and ponds in North Fork Snoqualmie basin. |

Table 41 - continued.

| Species | Habitat* |
|---|---|
| Red-legged Frog | During breeding season, found near ponds or other permanent water with extensive vegetation; egg masses laid in permanent bodies of water; during non-breeding season found in damp forests. Several specimens captured in damp woods along North Fork Snoqualmie River, Lennox Creek, and Sunday Creek. |
| Reptiles | |
| Northern Alligator Lizard | Usually under rotten logs, rocks or loose bark in cool, moist woodlands. Two specimens seen sunning themselves, one in a clearcut, another near a small creek, in North Fork Snoqualmie basin. |
| Common Garter Snake | Near water; wet meadows, marshes, drainage ditches and damp woodlands. Several specimens identified along roads, and one specimen found in bog pond #26 (Figure 12) in North Fork Snoqualmie basin. |
| Northwestern Garter Snake | Forest edges, brushy areas. One specimen found in old growth coniferous forest during bird census in North Fork Snoqualmie basin. |

*From Behler and King 1979, Wechsler personal communication, and this study.

habitat descriptions of the different species (from Behler and King 1979, and pers. commun., Douglas Wechsler, WDG, Seattle, Wash.).

Wetlands are essential for several amphibians in the project area, namely northwestern salamander, rough-skinned newt, western toad, Pacific treefrog, and red-legged frog. Other species, like Pacific giant salamander and tailed frog, are river dwellers. Of reptiles known to occur in the basin, common garter snakes are most closely associated with wetlands. Without the project, living conditions for all these animals should remain excellent, due to the many wetlands and diversity of habitats within the project area.

## Hunter and Trapper Use Studies

### Deer Hunter Use and Harvest

Interviews of deer hunters during the 1978 and 1979 hunting seasons indicate that the North Fork Snoqualmie basin received about 30 percent of total known weekend hunting pressure in the Snoqualmie Game Management Unit* (Table 42). Weekday hunter use of the management unit (Table 43) differed significantly from that on weekends (chi-square $p<0.01$). Approximately 38 percent of hunters in our weekday sample hunted the basin, more than any of the other areas within the management unit. This shift in hunting pressure probably results from weekday patterns of land closures to the public, due to logging activities.

Multiplying our figures for percent use, by total number of hunters checked for the season, we estimated that 2,243 use-days were spent deer hunting in the North Fork Snoqualmie basin during 1979 (Appendix H). This is probably close to the average annual deer hunter use in the basin, as total number of hunters passing through the North Fork Snoqualmie checking station was about average in 1979 (Table 44). This figure may still underestimate hunter use by a substantial margin. A one weekend check of all access roads to the Snoqualmie Game Management Unit showed that only 62 percent of hunters passed through the North Fork Snoqualmie checking station. The rest used other gates. Furthermore, undetermined numbers of hunters leave at night, after the checking station closes.

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*Hunting pressure in the Middle Fork Snoqualmie area and other infrequently checked parts of the management unit are not included in this total. Occasional hunter checks in these areas indicate that they receive only about 5 percent of total hunter use.

Table 42. Numbers and percentages of weekend deer hunters in known areas of Snoqualmie Game Management Unit, 1978 and 1979.

| Area hunted | 1978 Number | 1978 Percent | 1979 Number | 1979 Percent |
|---|---|---|---|---|
| 1. North Fork Snoqualmie Basin | 418 | 33 | 1,122 | 30 |
| 2. East of Spur 10 Gate | 530 | 42 | 1,572 | 42 |
| 3. North of South Fork Tolt River | 172 | 14 | 542 | 15 |
| 4. West of Spur 10 Gate | 154 | 12 | 501 | 13 |
| Total hunters interviewed | 1,274 | 100 | 3,737 | 100 |
| Total hunters passing through checking station | 4,239 | | 5,856 | |

Table 43. Numbers and percentages of weekday deer hunters in known areas of Snoqualmie Game Management Unit, 1979.

| Area hunted | Number | Percent |
|---|---|---|
| 1. North Fork Snoqualmie Basin | 113 | 38 |
| 2. East of Spur 10 Gate | 98 | 33 |
| 3. North of South Fork Tolt River | 31 | 10 |
| 4. West of Spur 10 Gate | 54 | 18 |
| Total | 296 | 100 |

Table 44. Numbers of deer hunters passing through North Fork Snoqualmie checking station, 1962-79.

| Year | Number of hunters |
|---|---|
| 1962 | 6,803 |
| 1963 | 9,166 |
| 1964 | 10,042 |
| 1965 | 7,795 |
| 1966 | 5,560 |
| 1967 | 2,999 |
| 1968 | 7,279 |
| 1969 | 3,961 |
| 1970 | 6,770 |
| 1971 | 6,243 |
| 1972 | 7,261 |
| 1973 | 5,633 |
| 1974 | 2,049 |
| 1975 | 3,931 |
| 1976 | 5,103 |
| 1977 | 3,782 |
| 1978 | 4,239 |
| 1979 | 5,856 |
| Yearly Average | 5,804 |

For 1978 and 1979, known annual weekend deer harvests from the North Fork Snoqualmie basin averaged 45 deer, 29 percent of the known harvest in the entire management unit (Table 45). Distribution of hunters in the management unit did not differ significantly from distribution of the deer harvest, for either year (chi-square $p>0.05$) (Table 46). This result indicates that hunter success rates are similar throughout the management unit.

To estimate total deer harvest in the North Fork Snoqualmie basin during 1979, we added our known weekend harvest to our estimated weekday harvest (Appendix I). The resulting estimate was a total harvest of 55 deer. This is a minimum estimate, however. Hunters leaving after the checking station closed, or through unchecked access roads, accounted for an unknown additional harvest.

Our study of hunter residence showed that two-thirds of all hunters passing through the Snoqualmie checking station were from Greater Seattle (Table 47). "Locals" comprised the second largest group of hunters. These figures suggest that much of the importance of the Snoqualmie Game Mangement Unit as a hunting area, including the North Fork Snoqualmie basin, lies in its proximity to a major metropolitan population center. It is reasonable to expect that as urban centers expand, fuel supplies tighten and their prices rise, hunter use will increase throughout the management unit.

Other Hunter and Trapper Harvest

Other game and furbearing animals for which we have harvest data in the vicinity of the proposed project are mountain goat, black bear, coyote, bobcat, beaver, and blue and ruffed grouse.

Each year, WDG issues 50 permits to hunt mountain goats in Goat Unit 12, which includes the North Fork Snoqualmie basin. Permit demand is high, averaging 468 applicants per year since 1965 (WDG 1979).

To gain insight into the relative importance of the mountain goat harvest in the vicinity of the proposed reservoir, we examined the yearly distribution of locations where mountain goats were harvested in Unit 12. Table 48 shows that there is an increasing trend in mountain goat harvest in the North Fork Snoqualmie area. Before 1970, the average reported kill in this area was 1.9 goats per year. Since 1970, the average goat harvest has been 4.0 goats per year, approximately 19 percent of the the total kill for Goat Unit 12. Apparently, the North Fork Snoqualmie area is becoming increasingly important for mountain goat hunting. Improved hunter access to, and knowledge of, goat populations may explain this trend.

Bear numbers and harvest in the project area are apparently still quite low, following special spring bear hunts in 1973, 1974, and 1977. During the latest of these hunts, an estimated 60 black bears were

Table 45. Numbers and percentages of deer harvested in known areas of Snoqualmie Game Management Unit, weekends 1978 and 1979.

| | Area hunted | 1978 Number | 1978 Percent | 1979 Number | 1979 Percent |
|---|---|---|---|---|---|
| 1. | North Fork Snoqualmie Basin | 44 | 32 | 46 | 27 |
| 2. | East of Spur 10 Gate | 58 | 42 | 66 | 39 |
| 3. | North of South Fork Tolt River | 18 | 13 | 25 | 15 |
| 4. | West of Spur 10 Gate | 18 | 13 | 32 | 19 |
| | Total | 138 | 100 | 169 | 100 |

Table 46. Distribution of hunters and deer harvest in Snoqualmie Game Management Unit, weekends 1978 and 1979.

| Area hunted | 1978 Hunters | 1978 Deer | 1979 Hunters | 1979 Deer |
|---|---|---|---|---|
| 1. North Fork Snoqualmie Basin | 418 (33%) | 44 (32%) | 1,122 (30%) | 46 (27%) |
| 2. East of Spur 10 Gate | 530 (42%) | 58 (42%) | 1,572 (42%) | 66 (39%) |
| 3. North of South Fork Tolt River | 172 (14%) | 18 (13%) | 542 (15%) | 25 (15%) |
| 4. West of Spur 10 Gate | 154 (12%) | 18 (13%) | 501 (13%) | 32 (19%) |

Table 47. Residence of deer hunters using the Snoqualmie Game Management Unit during 1979.

| Residence | Weekends | | Weekdays | | Total | |
|---|---|---|---|---|---|---|
| Greater Seattle (includes Lynnwood, Mountlake Terrace, Bothell, Kirkland, Redmond, Bellevue, Renton, Kent, Auburn, Federal Way) | 2,015 | (67%) | 191 | (65%) | 2,206 | (67%) |
| Local (includes Duvall, Carnation, Fall City, Preston, Snoqualmie, North Bend) | 561 | (19%) | 59 | (20%) | 620 | (19%) |
| Other King County | 230 | (8%) | 26 | (9%) | 256 | (8%) |
| Tacoma or Everett | 82 | (3%) | 9 | (3%) | 91 | (3%) |
| Other Pierce or Snohomish County | 100 | (3%) | 5 | (2%) | 105 | (3%) |
| Other Washington | 28 | (1%) | 4 | (1%) | 32 | (1%) |
| Out of State | 1 | (0%) | 0 | (0%) | 1 | (0%) |
| Total | 3,017 | (100%) | 294 | (100%) | 3,311 | (100%) |

Table 48. Distribution of reported mountain goat harvest in North Fork Snoqualmie area, 1958-1979. (Data are from WDG Annual Reports and Big Game Status Reports.)

| Year | Mt. Phelps | North Fork Basin | McClain Peaks | Twin Peaks | Goat Mt. | Sunday Creek & Lake | Philippa Cr. & Lk. Philippa | Calligan Lake | Lennox Creek & Mt. | Specific Area Unknown | Total Harvest N. Fork area | Total Harvest Unit 12 | % of Total Harvest |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1958 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 32 | 0.0 |
| 1959 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 21 | 4.8 |
| 1960 | - | - | - | - | - | - | - | - | - | - | - | 19 | - |
| 1961 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 21 | 0.0 |
| 1962 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 26 | 0.0 |
| 1963 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 21 | 9.5 |
| 1964 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 29 | 6.9 |
| 1965 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 21 | 4.8 |
| 1966 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 20 | 10.0 |
| 1967 | 1 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 1 | 0 | 6 | 20 | 30.0 |
| 1968 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 5 | 23 | 21.7 |
| 1969 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 21 | 9.5 |
| 1970 | 0 | 0 | 1 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 4 | 22 | 18.2 |
| 1971 | 1 | 2 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 5 | 24 | 20.8 |
| 1972 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 4 | 17 | 23.5 |
| 1973 | 1 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 4 | 21 | 19.0 |
| 1974 | 1 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 5 | 19 | 26.3 |
| 1975 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 23 | 8.7 |
| 1976 | 1 | 0 | 1 | 2 | 1 | 0 | 2 | 0 | 0 | 0 | 7 | 26 | 26.9 |
| 1977 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 21 | 9.5 |
| 1978 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 4 | 26 | 15.4 |
| 1979 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 3 | 15 | 20.0 |

killed in the North Fork Snoqualmie drainage (WDG 1978). Given time to rebuild, the black bear population in the project area may sustain a relatively high annual harvest.

The little information available on grouse harvest in the vicinity of the proposed project is obtained annually at the North Fork Snoqualmie checking station (Table 49). Many of these grouse are shot incidentally to deer hunting. Because the amount of effort put into checking grouse varies, and the data are not categorized by area of harvest, we really have no idea of the number of grouse harvested in the project area.

We obtained figures for annual furbearer harvest within the proposed reservoir boundary (Table 50) from three persons who regularly trap in the North Fork Snoqualmie basin. Beaver is the most heavily trapped furbearer, an average of about 50 being taken each year. Three or four bobcats are also trapped annually. In addition, hound-hunters harvest several bobcats. Wallace Scott (pers. commun., Hobart, Wash.) told us that he and a hunting partner take eight or nine bobcats out of the North Fork Snoqualmie drainage each year, two to four of which are usually killed within the proposed reservoir boundary. We stress that these figures may be only partial counts, because we do not know how many more people actually trap and hound-hunt in the project area.

## Other Recreation

During our field studies, we noticed that there were often many non-hunting and non-fishing recreationists using the North Fork Snoqualmie basin. A one-day survey at the North Fork Snoqualmie checking station showed that 208 (37%) of 568 recreationists interviewed, were not hunting (Table 51). We feel that over the year, non-hunting and non-fishing recreation in the basin equals, and possibly exceeds, hunting and fishing use. As with hunting and fishing use, we can expect an increase in other kinds of recreation in the project area, as nearby urban populations grow and rising travel costs make outdoor recreation close to home increasingly attractive.

## Habitat Evaluation Procedures (HEP)

Results of the baseline HEP of the project area, conducted in September 1980, are forthcoming in a FWS Coordination Act Report.

Table 49. Number of grouse checked at the North Fork Snoqualmie checking station during deer hunting season, 1962-1979.

| Year | Ruffed Grouse | Blue Grouse | Unident. Grouse sp. | Total |
|---|---|---|---|---|
| 1962 | 7 | 31 | | 38 |
| 1963 | 11 | 1 | 1 | 13 |
| 1964 | 18 | 13 | | 31 |
| 1965 | 12 | 10 | | 22 |
| 1966 | | | 34 | 34 |
| 1967 | | | 42 | 42 |
| 1968 | 27 | 13 | | 40 |
| 1969 | 27 | 13 | 4 | 44 |
| 1970 | 24 | 6 | | 30 |
| 1971 | 5 | 4 | 7 | 16 |
| 1972 | 16 | 9 | | 25 |
| 1973 | 8 | 2 | 1 | 11 |
| 1974 | 4 | | 7 | 11 |
| 1975 | | 2 | 26 | 28 |
| 1976 | | | 16 | 16 |
| 1977 | | | 7 | 7 |
| 1978 | 27 | 13 | | 40 |
| 1979 | 20 | 12 | | 32 |
| Yearly average | 11.4 | 7.2 | 8.1 | 26.7 |

Table 50. Reported annual furbearer harvest of three trappers within boundary of proposed North Fork Snoqualmie reservoir.

| Species | Number trapped per year |
|---|---|
| Muskrat | 6 |
| Beaver | 40-65 |
| Coyote | 3-4 |
| Mink | 1-2 |
| Bobcat | 3-4 |

Table 51. Results of one-day recreation survey at North Fork Snoqualmie hunter checking station, 4 November 1979.

| Type of Recreation | Number |
|---|---|
| Deer hunting | 360 |
| Camping, hiking, sightseeing | 113 |
| Target-shooting | 44 |
| Kayaking, canoeing | 41 |
| Wood-cutting | 4 |
| Gold-panning | 2 |
| Mushroom hunting | 2 |
| Trail-biking | 2 |

# IMPACTS

## Habitat

Natural selection produces organisms which use resources efficiently. This process results in wildlife populations which are balanced with their environments. When resources (e.g., food) increase, animal numbers expand to meet the supply. As resources decline, so do animal populations. Vacant wildlife habitat is filled quickly.

Removing habitat from an ecosystem reduces the ability of that ecosystem to support wildlife. If wildlife populations are at or near carrying capacity, as is generally assumed, then habitat removal will reduce wildlife in numbers equal to those living within or using the affected habitat. For species mobile enough to escape the direct effects of habitat removal, losses will result from competition between displaced animals and occupants of adjacent habitats. The only way displaced and occupant animals can coexist indefinitely, is if their population is below carrying capacity when the habitat is removed. Such an occurrence is unlikely, unless the species is a relative newcomer whose population is still expanding, or it is migratory and its population is limited by some other habitat. Species kept below natural carrying capacity by harvest pressure would experience, at most, temporary coexistence between displaced and occupant animals.

The argument, then, that an animal population displaced from its habitat can survive elsewhere, merely states that the population is below the carrying capacity of its environment. Assuming that the population would eventually have reached carrying capacity, displaced animals and occupants of adjacent habitats could not coexist. Future wildlife losses would then be even greater than those predicted from estimates of populations which are claimed to be below carrying capacity.

Table 25 (p. 152) shows acreages of habitat types within the proposed reservoir boundary. These figures represent the approximate amount of each habitat type potentially removed from the North Fork Snoqualmie basin ecosystem, if a reservoir were built. The picture is complicated by the possibility that some upland or wetland vegetation could remain or be created in upper pool levels, as at Howard Hanson or Chester Morse reservoirs. However, inspection of our Habitat Type Map (see Map insert) reveals that the reservoir would eliminate the majority of existing wetlands (marshes, swamps, bogs, and ponds) within the basin (Photo 34). The fact that 83 percent of known ponds in the basin lie within the proposed reservoir boundary illustrates this potential impact. Eliminating these wetlands would greatly reduce the habitat diversity which distinguishes the North Fork Snoqualmie basin.

Photo 34. A reservoir in the North Fork Snoqualmie basin would probably replace most wetlands with mudflats, which are exposed when the pool is lowered. Reservoir pictured here is Spada reservoir in the Sultan basin, about 23 miles north of the project area.

# Mammals

## Small Mammals

The proposed reservoir would inundate habitats which support at least 9,100 mice and insectivores during summer (Table 30, p. 160), and an unknown number of chipmunks, squirrels, and weasels. Vegetation clearing operations in the inundation zone, prior to filling, would probably kill many small mammals. Most of those which survived would be drowned when the reservoir was filled, or preyed upon while trying to evade rising water levels. Some small mammals living just inside the upper pool margin would disperse to surrounding habitats, where they, or the animals already occupying those habitats, would succumb to competition or predation. Road-building above the inundation zone would eliminate additional small mammal habitat.

Reservoir construction would thus result in a loss of small mammals equivalent to numbers whose habitats were flooded or otherwise eliminated. Species preferring wetlands, such as vagrant/dusky shrew, Townsend's vole, and Pacific jumping mouse, would be most severely impacted, because a greater proportion of wetland habitat would be eliminated than any other habitat within the basin. Impacts to wetland species might be lessened, however, if wetland vegetation persisted in or colonized upper parts of the inundation zone. We would expect some small mammal use of these areas when exposed, where there is sufficient cover.

## Medium-sized Mammals

Reservoir impacts to medium-sized mammals would be similar to impacts on small mammals. However, because of their greater mobility, more medium-sized mammals would likely survive flooding, only to starve or be eaten by predators. The proposed reservoir would eliminate habitats of undetermined numbers of mountain beavers and snowshoe hares from the basin. Some 10-14 river otters and 75 beavers would be flooded out of their habitats, along with unknown numbers of mink and muskrat. The severity of impact on wetland-associated species becomes clear when we point out that 82 of 99 known ponds in the basin would be inundated. Fluctuating water levels in a reservoir would provide little suitable beaver habitat to replace that lost to flooding.

Because beavers are, within limits, able to create their own habitat, a few might survive to start colonies on undammed streams. However, potential beaver habitat outside existing pond systems may be marginal, as suggested by the relatively small number of ponds outside the proposed reservoir boundary. Steeper slopes both lateral to and upstream of the proposed reservoir may explain this phenomenon. Future populations of mink and muskrat in the basin would depend largely upon the success of beavers in colonizing new areas. Beavers denning in river banks prior to inundation, and river otters living in the reservoir zone would

probably not find suitable vacant habitat, and would perish once their habitats were flooded.

Large Mammals

Black-tailed Deer. The proposed reservoir would flood prime winter-spring range for black-tailed deer. Pellet group counts indicate that over 350 deer would be displaced into adjacent habitats. In severe winters, the number may be even higher. Displaced deer would compete with animals already occupying adjacent habitats. Winter and spring foods for all competing animals could be depleted, resulting in an initial die-off of more than just the number of deer whose habitats were inundated. This process might take two or more years, depending upon severity of winter weather.

Eventually the deer population would restabilize at a new, lower level, reflecting the reduced winter-spring carrying capacity. Not only would there be fewer wintering deer on the basin floor, but summer populations throughout the drainage would be lower. This is because the reservoir area, prior to inundation, provided winter-spring habitat to deer which summer on adjoining slopes and ridges and up tributary valleys.

Reservoir impacts to deer which summer in the basin, but winter elsewhere, might be less severe. Studies in other areas have shown that winter-spring range usually limits deer populations. Therefore, animals displaced from their summer home ranges by the reservoir may find suitable habitat elsewhere in the basin. However, if summer and winter-spring ranges are in equal supply, then the proposed reservoir could reduce wintering deer populations in other river drainages. We have monitored deer which summer in the basin and migrate to winter ranges as far away as 18 km (11 mi). Some may move even farther.

Reservoir impacts to deer (and those who hunt them) would therefore not be confined to the zone of inundation. Lower summer deer density throughout the North Fork Snoqualmie basin is a likely result, with the additional possibility that winter deer densities would be reduced in some areas outside the basin.

Other Large Mammals. Large predatory mammals (coyote, black bear, bobcat, and cougar) might initially benefit from the reservoir. An abundance of displaced prey, many of which would starve, would provide ample food in the form of carrion or easily caught animals, even for predators displaced by flooding. Black bears would probably benefit least from this overabundance of prey, because the majority of their diet is vegetable matter.

Once prey populations had dropped to levels which the habitat could support, large predators would have difficulty finding food, and some would probably starve. Loss of wetland habitat could severely impact the bear population, because bears feed extensively on wetland vegetation during spring. We would expect an increase in bear damage to

sapling conifers around the reservoir, as competition forces bears to turn to this alternative food. The eventual impact of the reservoir on large, predatory mammals would be a reduction in their numbers equal to those which could be supported by the habitat which was flooded.

Reservoir impacts to mountain goats should be chiefly on their movements. Occasional goat sightings within the proposed reservoir boundary suggest that they migrate, perhaps seasonally, across the basin. A large body of open water (or mud) could impede these movements, or subject mountain goats to greater risk of predation.

Mountain goats may also use the basin floor for purposes other than travel. In Olympic National Park, marked mountain goats have been observed to descend several thousand feet to a valley floor for short periods in summer (pers. commun., Kenneth Raedeke, College of Forest Resources, University of Washington, Seattle, Wash.). Perhaps they do so to cool themselves near a stream, or to find some special food. Potential reservoir impacts to mountain goats in the project area can only be fully evaluated through marking studies.

## Birds

### Non-game Birds

Predicting reservoir impacts to non-game birds is complicated by the fact that many species are migratory, spending only part(s) of the year in the project area. In most cases, we do not know whether wintering habitat, breeding habitat, or migratory habitat limits their numbers. We therefore assume that any loss of habitat will result in a proportionate reduction in numbers of birds.

The proposed reservoir would inundate breeding habitats of more than 3,200 non-game birds (Table 37, p. 187). Unlike small mammals, most birds would escape direct effects of reservoir clearing and filling, unless done before young had fledged. Displaced birds would compete for food and nest sites with birds occupying adjacent habitats. Some might die, and many would not breed successfully. Within a few years at most, natural mortality of adult birds, coupled with lack of breeding success, would lower populations to levels which could be sustained by remaining habitats.

Non-game species suffering greatest proportional losses would be those which occupy wetlands, such as common yellowthroat and red-winged blackbird. This is because most wetlands in the basin would be inundated. Persistence of any existing wetlands after inundation could help mitigate this effect, especially if they were available (i.e., unflooded) during nesting season. Creation of new wetlands, either by the reservoir or by beavers, would probably take many years.

Cavity-nesters, such as woodpeckers, tree swallows, and chickadees, would also be severely reduced in the basin, because a disproportionate number of snags occur in and around wetlands (Photo 35). In addition, a large number of dippers would be eliminated, due to the many miles of stream flooded, and erratic or reduced flows below the dam.

Non-game birds possibly benefitting from the project include: 1) a few loons and grebes which could winter on the reservoir, although its acreage would be smallest at this time; 2) shorebirds which might feed on exposed mudflats; and 3) great blue herons which could forage along the shoreline and in shallow pools for fishes and amphibians. Negative impacts of the project to non-game birds far outweigh these few benefits.

Game Birds

Grouse. The proposed reservoir would eliminate breeding habitats of more than 80 blue grouse and an unknown number of ruffed grouse. Effects of inundation would be similar to those on non-game birds. Unfledged chicks might drown or be eaten by predators. Displaced adult grouse would compete with residents of habitats around the reservoir for food and nest sites. Increased adult mortality and reduced reproduction would eventually lower grouse populations to levels which remaining habitats could support.

Waterfowl. We did not estimate numbers of ducks in the project area, but our field observations indicate they are abundant during and after the breeding season. We expect severe reductions in breeding duck populations in the basin if a reservoir is built. Inundation would eliminate a large percentage of wetlands and river habitat, which many ducks require for nesting and raising broods.

Potential nest sites would exist for some pond ducks, such as mallard and green-winged teal, above the upper pool level. However, such sites would be far from the reservoir during much of the nesting season in April and early May. Wood ducks and hooded mergansers, which now populate many ponds in the project area, are unlikely to use a large, open reservoir. Pond duck populations in the basin would decline through dispersal to already occupied or marginal habitats, increased competition, reduced breeding success, and adult mortality. The net effect would be loss of those birds whose habitats were flooded.

Reservoir impacts to river ducks (harlequin duck and common merganser) would occur both within the inundation zone, as well as downstream. Flooding of many miles of river would eliminate all potential harlequin use of the affected stretch. Common mergansers, on the other hand, could perhaps adapt to reservoir life, as they breed on both streams and lakes. Large daily flow fluctuations below the main dam, and reduced flows between the reregulating dam and powerhouse would lower food supplies (aquatic insects and fishes) of both species along several more miles of river. River duck populations would decline as a result.

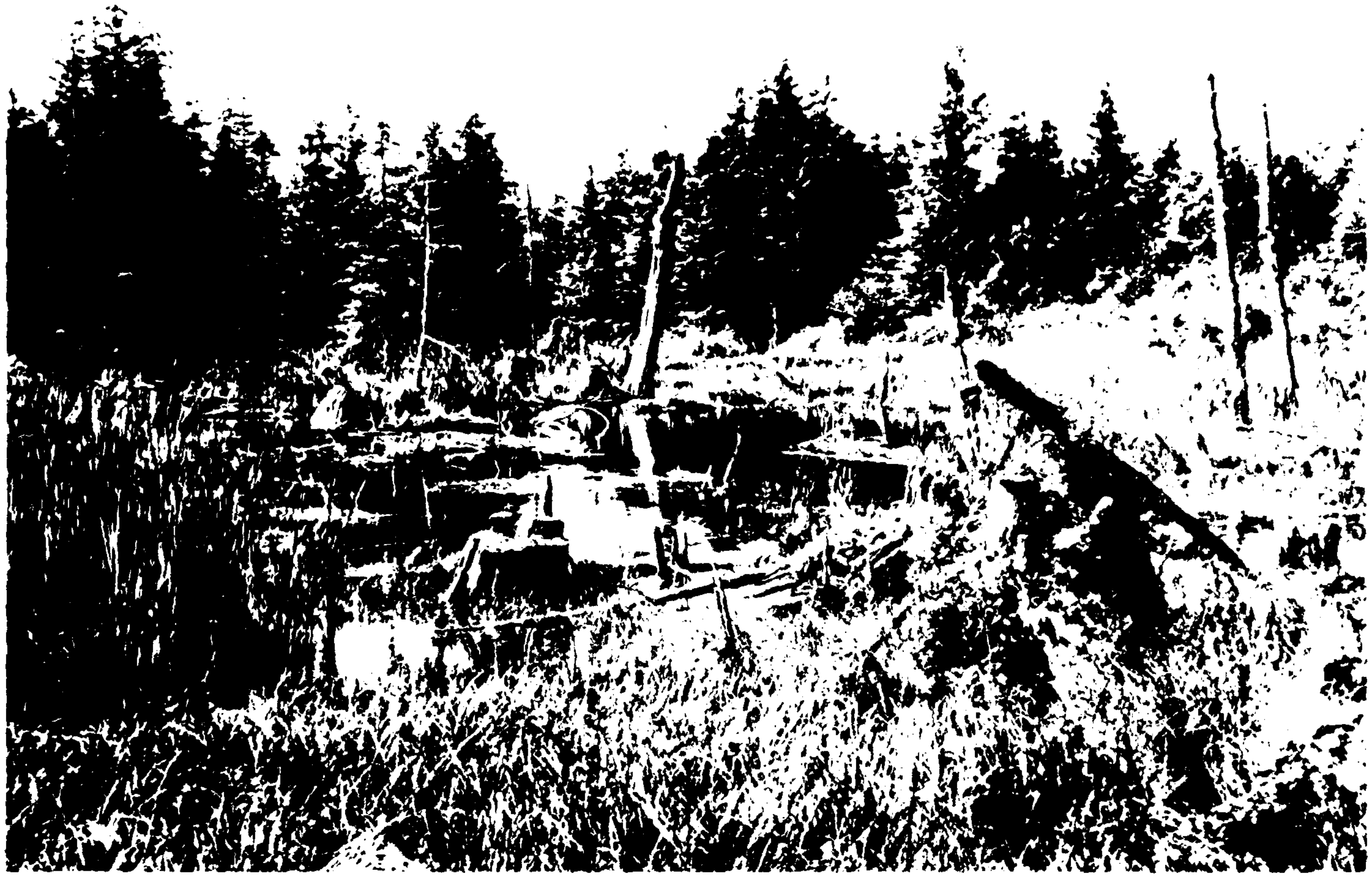


Photo 35. When beavers flood a forested habitat, they create snags, used by many birds for nesting and feeding.

WDG studies on Spada reservoir in the Sultan basin, suggest that winter waterfowl use of the project area might increase slightly, with small numbers of buffleheads, goldeneyes, and green-winged teal occupying the reservoir.

Band-tailed Pigeon. Project impacts to band-tailed pigeons would probably be minor. Our field observations indicate that most of these birds nest and feed on slopes and ridges above the level of the proposed reservoir.

Raptors

The proposed reservoir would eliminate some very good raptor habitat from the North Fork Snoqualmie basin. The tremendous diversity of cover within the inundation zone appears especially suited to sharp-shinned and Cooper's hawks, which hunt birds and small mammals by aerial ambush.

Large trees and snags along some stretches of river are also used as perches by larger raptors (e.g., bald eagle and red-tailed hawk), and are potential nest sites for small owls. We know of at least one kestrel nest which would be flooded. There may be several others as well. Raptors whose nest sites and hunting ranges were inundated would have to compete with their neighbors outside the reservoir. Populations would inevitably decline to levels which remaining habitats could support.

We are unsure how the reservoir would affect the pair of golden eagles nesting in the basin. In summer, they appear to do much of their hunting on slopes, riding thermals over huge clearcuts. Recent sightings indicate that golden eagles also occupy the basin in winter. If deeper snow on slopes reduces access to prey, then eagles might spend more time in winter hunting the valley bottom. Carrion may also be more available there, with the large concentration of wintering deer. In such a case, the reservoir could reduce the golden eagles' winter food supply.

Two species of raptors--osprey and bald eagle--frequently move into impounded areas where fishes and waterfowl are abundant. WDG studies on Spada reservoir have shown little use by either species, perhaps due to inadequate food or lack of suitable trees for nesting and perching. With relatively low numbers of fish and waterfowl predicted for the North Fork Snoqualmie reservoir, potential use by ospreys and bald eagles would be limited to a very few birds; and their presence would depend upon good nesting or perching sites.

## Amphibians and Reptiles

As discussed earlier, the proposed reservoir would eliminate a large proportion of wetland habitat types (marshes, swamps, bogs, and ponds) from the basin. Several amphibian species, e.g., northwestern salamander, rough-skinned newt, western toad, Pacific treefrog, and red-legged frog, for which wetlands are essential, would be greatly

reduced. Fluctuating water levels in a reservoir would likely provide little suitable habitat for most amphibians to help offset these losses. River-dwelling amphibians, such as Pacific giant salamander and tailed frog, would also be eliminated from the area of the proposed reservoir. However, impacts to overall numbers of these latter species in the basin might be less than for pond-dwelling species, because a larger proportion of river habitat would remain unaffected.

Of reptiles known to occur in the basin, the common garter snake, which favors wetlands, would probably be most impacted by a reservoir. Northwestern garter snake and northern alligator lizard would be reduced roughly in proportion to overall land surface inundated.

## Hunter and Trapper Use

### Deer Hunter Use and Harvest

With the proposed reservoir, we predict fewer deer harvested and fewer hunters using the North Fork Snoqualmie basin than without the project. Inundation would shift hunters, and deer, into areas surrounding the reservoir. Initially the percentage of hunters killing deer could increase, due to the large number of displaced deer. However, as the deer population declined in the basin, success of deer hunters would also decline--to below pre-project levels. Lowered hunter success in the basin would probably cause some persons to hunt elsewhere in the game management unit, or in other parts of the state. As the state population expands, projects like the proposed reservoir, which crowd more hunters onto fewer good hunting lands, could discourage a significant amount of hunting recreation.

### Other Hunter and Trapper Harvest

Assuming hunter access to mountain goats is maintained through construction of new roads, the impact of the reservoir on goat hunting would depend upon how it affects the local mountain goat population. These effects can only be determined through marking studies.

The reservoir would eliminate hunting opportunities for black bear, bobcat, and grouse within the zone of inundation. Bobcat hunting in the basin would be most severely reduced, because much of it is done on the valley bottom after snowfall, when slopes and ridges are inaccessible.

Inundation of most of the basin wetlands by a reservoir would sharply curtail trapping, which is directed largely at beaver and other aquatic furbearers. Trappers whose favorite haunts were eliminated could not simply go elsewhere to trap. Wetlands are localized habitats, and most of those which produce good furbearer populations are either already claimed by trappers, or their access is restricted. Thus, we believe that the net effect of the reservoir on trapping would be to eliminate

the amount of trapping which presently occurs in those habitats potentially inundated. An annual harvest loss of some 50 beavers and lesser numbers of other furbearers could be expected.

## Other Recreation

Having spent the better part of two years in the project area, our impression is that recreation other than hunting and fishing equals or exceeds hunting and fishing recreation. As nearby urban centers expand, and costs of travel discourage longer trips, we expect an increase in camping, hiking, and other forms of recreation in the North Fork Snoqualmie basin. The proposed reservoir would reduce some kinds of recreational opportunities, while increasing others. We urge that recreational benefits of the project be evaluated only after thorough field study.

## MITIGATION CONCEPTS

The goal of mitigation is to avoid, reduce, and/or offset project impacts to wildlife. We have prepared a conceptual plan to help meet this objective, should the proposed North Fork Snoqualmie reservoir be authorized for construction. Some of our proposed mitigation measures have been used successfully on projects elsewhere; others we have devised ourselves. Several measures would require outright purchase of lands, or a cooperative management agreement between WDG and the landowner.

Sequence of the following mitigation ideas does not imply priority; nor do we necessarily wish to limit ourselves to these methods, should other more effective mitigation tools arise. If the reservoir project is implemented, WDG expects to help plan wildlife mitigation, monitor its success, and propose new measures where needed to fully mitigate wildlife losses. The following methods can be used to help achieve this goal.

### 1. Plant Hatchery Fish in Reservoir and Some Beaver Ponds

The development agency should fund annual plantings of 70,000 to 80,000 rainbow trout fingerlings (about 150 per surface acre at minimum pool) in the proposed reservoir. These fish should be from a later-spawning stock of rainbow trout which would help reduce the deleterious effects of reservoir drawdown on spawning and rearing.

In consultation with WDG biologists, plant suitable numbers of cutthroat trout in those beaver ponds and artificial embayments above the reservoir's high pool elevation, which may be heavily fished because of their proximity to roads.

Construction of a trout hatchery capable of producing 600,000 fish annually, as presented in the COE Reconnaissance Report (1976), would probably not be necessary. Adequate numbers of fish could be produced at the WDG Tokul Creek Hatchery with improvement of the present water supply system and construction of new raceways.

### 2. Supply Recommended Instream Flows

The development agency should supply instream flows which will maintain a desirable trout fishery in the lower river. We recommend at least 240 cfs in the river downstream of the proposed main dam, except when natural flows would be less. A flow of at least 340 cfs should be

provided downstream of any dam built near Spur 10 bridge (RM 6.9), except when natural flows would be less.

### 3. Improve Reservoir Tributary Streams for Trout Rearing and Spawning

We recommend placement of large boulders in Sunday and Lennox Creeks to improve juvenile trout rearing habitat. After remaining in the streams for one to three years, these fish would move into the reservoir and contribute to its sport fishery.

Boulders, 0.6 to 1.0-m (2.0 to 3.3-ft) across, should be airlifted into place with a helicopter to minimize disturbance to the stream bed. Using a cable sling or a special rock tong, a small crew of men can place up to 30 boulders per hour. This technique was used successfully in a remote stream on Vancouver Island, British Columbia in 1977 and 1978. Cost at that time was estimated at $20 to $30 per boulder (Ward and Slaney 1979).

In Sunday Creek, large boulders should be placed in an approximately 1-mile long stream section from the reservoir's high pool elevation to just above the most upstream bridge (Fig. 17, p. 49 and Photo 14, p. 50). In Lennox Creek, boulders should be placed in an approximately 0.25 mile stream section from the reservoir's high pool elevation upstream to just beyond Forest Service Road 2527 (Fig. 19, p. 54 and Photo 17, p. 55). In consultation with WDG biologists, boulders should be placed in clusters of three to seven or in rows pointing downstream at a 45° angle to the bank to form deflectors.

These boulders would provide cover and sheltered backwaters for trout fry and juveniles. In addition, hollows in the stream bed are carved out just downstream of the structures by the action of water flowing over them during periods of high runoff. These "pockets" are used by young salmonids during periods of low flow. Ward and Slaney (1979) discovered that boulder placements in the Keough River on Vancouver Island increased the number of steelhead trout fry by as much as 50 percent. They estimated that the cost of placing boulders would be recovered in 10 years or less, from benefits added to the fishery.

As additional instream cover, all tree trunks, logs, and brush now present in the upper river or tributary streams, should be left in place. However, excessive amounts of debris in streams (large log jams) such as those generated in logging operations, are not beneficial. They should be prevented or, in consultation with WDG biologists, removed.

We recommend that an attempt be made to plant riparian vegetation and stabilize the wide braided channels of upper Sunday Creek and lower Lennox Creek. Boulders placed adjacent to one another, in a row, and at

a 45$^{o}$ angle to the bank, could form deflectors which might stabilize the parts of these braided channels nearest the bank. After a few years, sandbar willows such as Salix exigua or Salix fluviatilis, could be planted behind the deflectors. These plantings would benefit both aquatic and terrestrial wildlife.

Near RM 0.2 of GF Creek, a large log forms a 1-m (3.3-ft) fall and upstream migration barrier. This log should be removed by helicopter to allow access to spawning areas in the upper creek for reservoir fish.

### 4. Minimize Downstream River Temperature Changes

We recommend that the development agency provide temperature control (to the extent possible) in the North Fork Snoqualmie River downstream of the proposed dam. An attempt should be made to minimize differences between dam-induced and natural river temperature regimes. Incorporation of multi-level fixtures on the dam to draw off water for different reservoir levels, is one possible method.

### 5. Obtain a Public Fishing Access Easement Along the River

A 25-ft-wide public fishing access easement along both sides of the river should be obtained by the development agency. It should run from the proposed dam downstream to the river's mouth, but exclude Black Canyon except for a 200-ft section of river near the steep access trail. Unlike the mitigation presented in the COE Reconnaissance Report (1976), we believe a public access strip through the entire Black Canyon is probably unnecessary. Except for the tiny section mentioned, most areas are unfishable due to the steep canyon walls.

### 6. Monitor Accidental Flushing of Fish from the Reservoir

During years with abnormally large reservoir drawdowns, accidental flushing of fish from the reservoir should be monitored. A moveable fyke net could be suspended by cable in various parts of the dam tailrace. The number of fish being flushed out of the reservoir could be estimated from the proportion of fish caught in the net. In consultation with WDG biologists, an attempt should be made to minimize fish flushing. For example, a barrier net could be installed along the upstream face of the dam. This technique has been successful in Banks Lake (Stober et al. 1979).

## 7. Fund Studies of Downstream Ramp Rate Effects in the River

After the dam is built and downstream ramp (fluctuation) rates in the river are known, field studies of their effects on juvenile fish and benthos should be funded and instituted. In consultation with WDG biologists, ramp rates can be modified to minimize their effects on stream biota.

## 8. Investigate Enhancement of Stream Production by Addition of Nutrients

Should the project ever be authorized for construction, an investigation should be made into the feasibility of increasing fish production in the reservoir's major tributaries by adding nutrients such as phosphate.

Stockner and Shortreed (1978) increased algal biomass up to eight times by adding phosphate to water from an oligotrophic stream on the west coast of Vancouver Island. They postulated that results from their stream enrichment experiments could be validly extrapolated to many other coastal oligotrophic streams in the Pacific Northwest. Higher trophic levels, such as aquatic insects and fish, could also benefit from nutrient enhancement.

In the North Fork Snoqualmie basin, a nutrient addition could be in the form of calcium phosphate introduced from a point source (pers. commun., Prof. Eugene Welch, Univ. of Wash., Seattle, Wash.). Nutrient addition could be limited to summer and early fall, when temperature and stream productivity levels are relatively high, yet flows are reduced. This augmentation also would benefit the reservoir fishery. However, the quantity of nutrients added to the streams would have to be monitored, so as not to degrade water quality in other downstream parts of the Snohomish River system.

Since nutrient enhancement of stream production is a relatively new technique, we recommend a more thorough study of its feasibility at a later date, such as when the proposed North Fork Snoqualmie dam is authorized.

## 9. Selectively Clear Timber and Brush from the Reservoir Site

Inundated trees and brush provide cover and feeding areas for fish, while exposed trees provide roosting and nesting habitat for waterfowl,

raptors, and other birds. Timbered areas should be retained at stream mouths, in shallow coves, and in patches between the reservoir's high and low pool elevations. This last recommendation ensures that some trees would be in the littoral zone, regardless of the reservoir's water level. To minimize short-term impacts to terrestrial wildlife, clearing of vegetation in the reservoir site would best be done in fall, after the breeding season of most animals and before concentrations of wintering deer move into the inundation zone. Initial filling of the reservoir in fall would also minimize impacts to fish spawning and egg incubation.

## 10. Establish Buffer Strips along the River and Tributary Streams

Riparian vegetation in the form of buffer strips is important to both terrestrial and aquatic wildlife. Buffer strips provide temperature control, act as sediment filters, supply cover, and furnish organic detritus for stream organisms (Meehan et al. 1977). Riparian zones provide food, cover, rest sites, travel corridors, and breeding habitats for terrestrial organisms (WDG, Streamside Management Zone Inventory 1980).

We define buffer strips as those areas on each side of a water course which are left undisturbed. They are not subject to logging and its associated activities, nor pesticide application. We recommend 61-m (200-ft) buffer strips on both sides of the following streams:

a) North Fork Snoqualmie River from the lower end of Black Canyon, upstream to the Alpine Lakes Wilderness boundary, excluding those areas that would be inundated;

b) Lennox Creek from its mouth in the proposed reservoir to the wilderness boundary;

c) Sunday Creek from its mouth in the proposed reservoir to the wilderness boundary;

d) Philippa Creek from its mouth in the proposed reservoir to Philippa Lake.

We recommend 30.5-m (100-ft) buffer strips on both sides of GF Creek from its mouth in the proposed reservoir, upstream to Weyerhaeuser road 30 A.

## 11. Create Browseways to Improve Winter and Spring Deer Ranges

Browseways are openings in a forest, created by thinning or totally removing dense stands of trees. Light penetrates these openings, promoting growth of shrubs and other deer forage. To help reduce deer losses caused by inundation of winter and spring ranges, browseways should be created in pole stage forests around the reservoir. Improving the mix of cover and forage would allow more deer to survive in the remaining habitat. Other wildlife, such as snowshoe hare, bobcat, and song sparrow, would also benefit.

Browseways below 762 m (2,500 ft) el. would probably be most useful to deer, because of heavy snow accumulation at higher elevations. Browseways would not be created in old growth forest, which is already excellent deer wintering habitat. Thomas (1979) recommended that openings be no greater than 366 m (1,200 ft) wide. Forested areas, which provide thermal and hiding cover, should be 0.8-2 ha (2-5 acres) and at least 92 m (300 ft) wide. Cuts should be made in irregular patches and strips, and maintained on a 20-25-yr rotation (Juelson et al. 1980). Heavy slash accumulation in browseways will inhibit shrub growth, so slash should be piled. Cover next to natural openings such as streams and wetlands would be retained. The proportion of browseways to forested areas should be about 1:1 (Juelson et al. 1980).

## 12. Create Artificial Wetlands for Wildlife

Loss of wetland habitat types could be partly offset by manipulating the reservoir to create new wetlands. An alternative scheme would be to build and maintain ponds and marshes at suitable sites along the reservoir shore. Likely spots for pond construction would be shallow-gradient areas with natural year-round seepage. Small streams with fish spawning and rearing potential would be avoided.

Ponds should be excavated in the drawdown area near shore. Each pond would be separated into a series of smaller ponds, by using excavated material to create a series of terraced ring dikes extending into the inundation zone (Slaney and Co. 1973). During drawdown, ponds would be filled by natural seepage, and connected by spillways over dikes, resembling a series of beaver ponds. Sizes and depths of ponds would depend upon the size of stream supplying them. A combination of deep and shallow water areas with islands would provide habitat for fish, and wetland mammals and birds. When the pool was raised, floating log booms just offshore would help keep waves from eroding dikes (U.S. Army Corps of Engineers 1980b).

To encourage wildlife use, rushes, sedges, and cattails should be transplanted to pond shallows. Willow, cottonwood, and other native vegetation would be planted along dikes. Open water, interspersed with islands and marshland, should create habitat favorable to mink, muskrat, beaver, ducks, herons, and marsh passerines. Additional wildlife use could be encouraged by leaving or creating snags in and around ponds. Annual maintenance of artificial wetlands would probably be needed, especially at first.

### 13. Seed Drawdown Areas to Provide Food for Wildlife

Annual seeding of drawdown areas could increase winter and spring food available to deer, helping to reduce deer losses due to flooding of habitat. In Tennessee, experimentally planted forage in a reservoir inundation zone was an important food source to white-tailed deer (Fowler and Whelan 1980). Slaney and Co. (1973) also found that deer around Ross Lake ate naturally occurring plants in drawdown areas during spring. Other possible wildlife benefits of drawdown seeding include: 1) waterfowl eating the plants; 2) young fishes finding food or cover among inundated drawdown plants; and 3) annual decay of drawdown plants, providing nutrients to food webs of reservoir fishes.

Seeds of grasses and herbs best suited to deer use in drawdown areas could be obtained from local seed companies. Seeds would be spread aerially over selected drawdown locations. Optimal timing for germination and wildlife use would be determined experimentally. More than one application per year might be necessary to yield maximum winter and spring forage for deer.

### 14. Fertilize Winter and Spring Deer Ranges

To increase browse production for deer, remaining winter and spring ranges could be fertilized. This procedure would help reduce deer losses resulting from flooding of habitat. Slaney and Co. (1973) found significant increases in plant growth with several types of fertilizer applied to test plots at 112 kg/ha (100 lb/acre). Browseway and planted drawdown areas could be fertilized, perhaps in conjunction with aerial drawdown seeding. Nutrient levels in the reservoir would be monitored to prevent deterioration of water quality.

### 15. Retain and Create Snags

Roughly one-fourth of the bird species breeding in the North Fork Snoqualmie basin nest in snag cavities (Photo 36). So do some mammals.

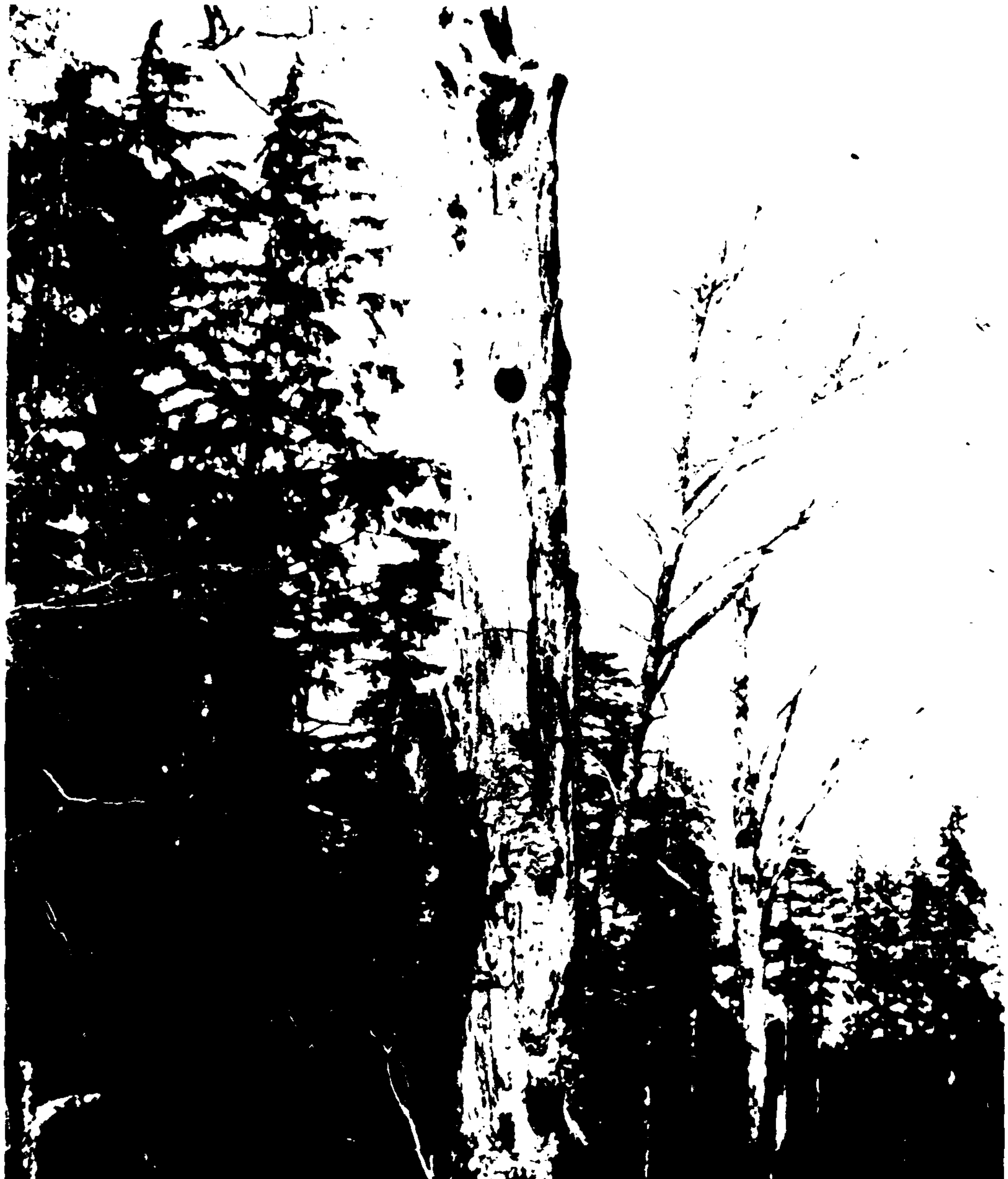


Photo 36. Snags are an important nesting and feeding habitat for many kinds of wildlife. Nest-hole above was probably created by a pileated woodpecker.

Many other birds feed on insects which live in snags. To help mitigate project losses of this important habitat, snags and some living trees should be left in upper levels of the reservoir. Live trees will be killed by flooding, thus replacing older snags which decay and fall.

Outside the reservoir, snags should also be left standing. A continuous supply can be maintained by topping or girdling live trees on a rotational basis. This of course means preserving trees for future snag use. Snags of several heights, diameters, and stages of decay should be maintained to encourage the highest diversity of wildlife use (Thomas 1979). Snags left or created near stream mouths, where reservoir fish are expected to concentrate, may especially benefit ospreys and some cavity-nesting ducks. Snags in and around artificial ponds will also receive heavy use by wildlife.

## 16. Preserve Old Growth Forest--A Threatened Habitat

Most of western Washington's old growth forest has been logged. What little remains is rapidly being converted to seral forest. Animals which require old growth, such as fisher, flying squirrel, and spotted owl, are consequently vanishing. Deer wintering in high snowfall areas are also losing critical habitat (Taber and Raedeke 1980). Our mitigation plan, therefore, calls for preserving a large tract, or tracts, of old growth forest currently destined for cutting in the basin (Photo 37).

Old growth timber in buffer strips could partly satisfy preservation goals. However, adjoining stands of old growth would also be needed, because many animals specialized to this habitat type require large expanses of old growth. Possible mitigation sites include old growth forest in the upper North Fork Snoqualmie, Lennox Creek, and Phillipa Creek drainages. Preserving old growth forest in these areas could also help satisfy goals to maintain snags in the basin.

## 17. Build Nest Structures for Ducks and Ospreys

Construct nesting habitat for ducks and ospreys to encourage their use of the reservoir. Islands for waterfowl nesting could be created by piling material excavated from artificial ponds at appropriate levels in the inundation zone. Alternatively, floating nesting rafts could be attached to pilings driven into drawdown areas. Floating structures might be more effective than islands, because large reservoir fluctuations could expose nests to predation or flooding.

Nest boxes for wood ducks can also be constructed within the inundation zone (Nelson et al. 1978), as well as artificial nesting platforms

Photo 37. Old growth forest, a vanishing community.

for ospreys (Call 1978). Adequate rearing habitat and food supplies for waterfowl and ospreys must exist for nest structures to be used.

## 18. Change Forest Practices to Benefit Wildlife

a. If old growth forest is to be logged, cut only some of the trees, leaving all snags and enough mature timber to maintain at least 60 percent canopy closure. This practice would preserve some nesting and feeding habitat for many birds and mammals which prefer old growth forest. In addition, remaining thermal cover and increased forage in the partly-logged forest could continue to sustain wintering deer.

b. If clearcutting is continued, cut smaller, irregularly-shaped openings. For optimal deer use, dimensions of openings and forested areas would be the same as for browseway thinning. Patches of conifers could be left standing in clearcuts to provide cover for raptors, deer, and other wildlife. Slash should be piled to prevent it from inhibiting shrub growth. Slash piles would provide good feeding habitat for woodpeckers, and cover for small mammals and ground-feeding birds.

Clearcuts should be placed at ends of roads, rather than adjacent to major roads, to reduce disturbances to wildlife by vehicles (Taber and Raedeke 1980). Alternatively, clearcuts should be screened from roads by leaving buffer strips of vegetation, or by using topography (Thomas 1979).

c. Cease pesticide applications to encourage diversity of habitats and wildlife. Spraying herbicides to kill broadleaf vegetation competing with conifers, reduces wildlife habitat diversity by creating a monoculture. Insecticide application further reduces habitat diversity by killing insects which help produce snags. Some insecticides also kill forest birds and other animals (Herman and Bulger 1979). Wildlife losses caused by the project could therefore be partly mitigated by halting spraying of biocides in the basin. Nuisance roadside vegetation could be removed manually.

## 19. Build Canal Crossings and Escape Ramps for Mammals

The power canal downstream of the reregulating dam may impede daily and seasonal movements of deer and other mammals. In consultation with biologists, bridges should be built across the canal to allow for continued mammal movements. These crossings would be constructed near established game trails, and would appear as natural as possible, preferably solid structures covered with soil. Ramps with low-gradient slopes (3:1 or 4:1) should also be built into the canal to allow animals enter-

ing the canal to escape. Designs and costs of wildlife crossings and escape ramps are given in Nelson et al. (1978).

### 20. Build and Rehabilitate Roads to Minimize Wildlife Impacts

In consultation with biologists, construct road crossings of streams, using bridges or culverts which allow fish passage. To minimize sedimentation impacts to fish spawning and egg incubation, all construction next to streams should be avoided from 1 February to 1 July.

Revegetate borrow sites and spoils from project road construction, using shallow-rooted grasses, and native herbs, shrubs, and trees. Additional mitigation could be gained by revegetating existing borrow sites and road spoils, and gathering slash into piles to allow shrub growth and create new wildlife habitat.

### 21. Manage Habitat in Power Line Corridor for Wildlife

To increase wildlife values of the transmission line corridor, we recommend several measures. First, natural vegetation should be allowed to regenerate, rather than planting and maintaining grasses. All snags should be left in place. Slash should be piled to create habitat for birds and small mammals, and to allow shrub growth. Herbicides would not be used to control vegetation. Instead, trees which threaten power lines would be removed manually. To minimize disturbance to wildlife, vehicle access would be restricted to official use, through locked gates.

### 22. Preserve or Enhance Other Sites

If full mitigation cannot be achieved in the North Fork Snoqualmie basin, other sites should be chosen for preservation or enhancement. Preservation of an area would constitute mitigation only if it were threatened with imminent alteration or destruction. Wetlands and old-growth forests represent uncommon habitat types which would be considered for protection. Preservation could be achieved through purchase, cooperative agreement with landowner(s), or other arrangement.

Potential sites for wildlife habitat enhancement include other nearby reservoirs and streams. Some of the mitigative measures suggested above, such as browseway thinning, wetland creation, drawdown seeding, instream boulder placement, and streambank revegetation, could be

applied for example, to the South Fork Tolt Reservoir or the South Fork Snoqualmie River.

Off-site enhancement could not, of course, be considered on-site mitigation for these other projects. Success of off-site enhancement would be monitored concurrently with mitigation on project lands.

### 23. Fund Studies to Monitor Impacts and Mitigation

Part of the mitigation process would be to fund biological studies to monitor impacts of the project and success of mitigative measures. Studies should be conducted for at least 10 years after project completion. If mitigative measures were deemed unsuccessful, then new measures would be tried and their successes monitored.

## LITERATURE CITED

Baxter, R. M., and P. Glaude. 1980. Environmental effects of dams and impoundments in Canada: experience and prospects. Can. Bull. Fish. Aquat. Sci. 205. 34 pp.

Behler, J. L., and F. W. King. 1979. The Audubon Society field guide to North American reptiles and amphibians. Alfred A. Knopf, New York. 719 pp.

Binns, N. A. 1972. An inventory and evaluation of the game and fish resources of the upper Green River in relation to current and proposed water development programs. Univ. Wyoming, Water Resour. Res., Report. Wyoming Fish Game Comm. 196 pp.

Bisson, P. A., and J. R. Sedell. In prep. The relationship of channel and bank stability, pool quality, and debris to fish populations in southwest Washington streams.

Bovee, K. D. 1978. Probability-of-use criteria for the family salmonidae, Coop. Instream Flow Serv. Group, Fort Collins, CO. 88 pp.

Bovee, K. D., and R. T. Milhous. 1978. Hydraulic simulation in instream flow studies: theory and techniques. Coop. Instream Flow Serv. Group, Fort Collins, CO.

Brett, J. R., R. E. Shelbourn, and C. T. Sharp. 1969. Growth rate and body composition of fingerling sockeye salmon, *Oncorhynchus nerka*, in relation to temperature and ration size. J. Fish. Res. Board Can. 26:2363-2393.

Bustard, D. R., and D. W. Narver. 1975. Aspects of winter ecology of juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Salmo gairdneri*). J. Fish. Res. Board Can. 32:667-680.

Cairns, J. Jr., and K. L. Dickson. 1971. A simple method for the biological assessment of the effects of waste discharges on aquatic bottom-dwelling organisms. J. Wat. Poll. Cont. Fed. 43(5):755-770.

Call, M. W. 1978. Nesting habitats and surveying techniques for common western raptors. Tech. Note TN-316. U.S. Bureau Land Mgmt., Denver, CO. 115 pp.

Casne, S. R. 1975. Production and food of salmonid populations in three sections of the Cedar River, Washington. M.S. Thesis, Univ. Washington, Seattle. 57 pp.

$CH_2M$ Hill, 1978. Copper Creek environmental assessment. Draft environmental report. City of Seattle Dept. of Lighting. Seattle, WA. 228 pp.

Chapman, D. W. 1979. Salmon and steelhead in western Washington: an ecological report. Prepared for use in United States et al. vs State of Washington et al., Civil No. 9213-II, U.S. District Court, Western District of Washington. 246 pp.

Chapman, D. W., and E. Knudsen. 1980. Channelization and livestock impacts on salmonid habitat and biomass in western Washington. Trans. Amer. Fish. Soc. 109:357-363.

City of Seattle, Department of Lighting. 1973. The aquatic environment, fishes, and fishery of Ross Lake and the Canadian Skagit River. Interim Rep. No. 2., Vol. 1. Seattle, WA 378 pp.

Coffman, W. P. 1978. Chironomidae, in an introduction to the aquatic insects of North America. Pages 345-375 in R. W. Merritt and K. W. Cummins, eds. Kendal/Hunt Publ., Dubuque, Iowa.

Congleton, J. L., S. R. Foley, H. J. Foss, and J. G. Osborn. 1977. Observations on the natural history of fishes in Tolt Reservoir and Walsh Lake. City of Seattle Water Dept. 17 pp.

Coutant, C. C. 1962. The effect of a heated water effluent upon the macroinvertebrate riffle fauna of the Delaware River. Proc. Acad. Sci. 36:58-71.

——————. 1968. Effects of temperature on the development rate of bottom organisms. In Annual Report for 1967. USAEC Div. Biol. and Medicine, Battelle-Northwest, Richland, WA. Pp. 9.13-9.14.

Edington, J. M., and A. H. Hildrew. 1973. Experimental observations relating to the distribution of net-spinning Trichoptera in streams. Verh. Int. Verein. Limnol. 18:1549-1558.

Edmunds, G. F., S. L. Jensen, and L. Berner. 1976. The mayflies of North and Central America. Univ. Minnesota Press, Minneapolis, MN. 330 pp.

Elliott, J. M. 1972. Effects of temperature on the time of hatching in Baetis rhodani (Ephemeroptera: Baetidae). Oecologia 9:47-51.

Fairbanks, R. L. 1979. An evaluation of the pellet-group survey as a deer and elk census method in western Washington. M.S. Thesis, Univ. Washington, Seattle. 96 pp.

Fillion, D. W. 1967. The abundance and distribution of benthic fauna of three mountain reservoirs on the Kananaskis River in Alberta. J. Applied Ecol., Vol. 4, No. 1. 1-11 pp.

Fowler, D. K., and J. B. Whelan. 1980. Importance of inundation zone vegetation to white-tailed deer. J. Soil and Water Conserv. Jan-Feb. Pages 30-33.

Fredeen, F. G. H. 1977. Some recent changes in black fly populations in the Saskatchewan River system in western Canada coinciding with the development of reservoirs. J. Can. Water Resour. 2(3-4):90-102.

Freese, F. 1962. Elementary forest sampling. Agricultural handbook No. 32. USDA For. Serv. 89 pp.

Gard, R. 1961. Effects of beaver on trout in Sagehen Creek, California. J. Wildl. Mgmt. 25:221-242.

Gislason, J. C. 1980. Effects of flow fluctuation due to hydroelectric peaking on benthic insects and periphyton of the Skagit River, Washington. Ph.D. Dissertation, Univ. Washington, Seattle. 163 pp.

Gore, J. A. 1977. Reservoir manipulations and benthic macroinvertebrates in a prairie river. Hydrobiologia 55:113-123.

Graybill, J. P., R. L. Burgner, J. C. Gislason, P. E. Huffman, K. H. Wyman, R. G. Gibbons, K. W. Kurko, Q. J. Stober, T. W. Fagnan, A. P. Stayman, and D. M. Eggers. 1979. Assessment of the reservoir-related effects of the Skagit project on downstream fishery resources of the Skagit River, Washington. City of Seattle, Dept. Lighting. Seattle, WA 602 pp.

Grimas, U. 1961. The bottom fauna of natural and impounded lakes in northern Sweden. Inst. Freshwater Res. Drottningholm, Sweden. 42:183-237.

___________. 1962. The effect of increased water level fluctuation upon the bottom fauna of Lake Blasjon, northern Sweden. Inst. Freshwater Res. Drottningham, Sweden. 44:14-41.

Harestad, A. S. 1979. Seasonal movements of black-tailed deer on northern Vancouver Island. Ph.D. Dissertation. Univ. British Columbia, Vancouver. 99 pp.

Haslam, S. M. 1978. River plants. Cambridge Univ. Press. London, England.

Herman, S. G., and J. B. Bulger. 1979. Effects of a forest application of DDT on nontarget organisms. Wildl. Monogr. No. 69. 62 pp.

Hines, W. W. 1975. Black-tailed deer behavior and population dynamics in the Tillamook Burn, Oregon. Wildl. Res. Rep. No. 5, Oregon Wildl. Comm., Corvallis, Oregon. (Fed. Aid to Wildl. Restoration, Proj. No. W-51-R.) 31 pp.

Hoffman, C. E., and R. V. Kilambi. 1971. Environmental changes produced by cold-water outlets from three Arkansas reservoirs. Water Resour. Res. Ctr. Publ. No. 5, Univ. Arkansas, Fayetteville.

Holmes, N. T. H., and B. A. Whitton. 1977. The macrophytic vegetation of the River Tees in 1975: observed and predicted changes. Freshwater Biol. 7:43-60.

Hynes, H. B. 1972. The ecology of running waters. Univ. Toronto Press. 555 pp.

__________. 1975. The stream and its valley. Int. Verh. Limnol. 19:1-15.

Juelson, T., W. Nelson, and S. Cooley. 1980. Annual report and on-site wildlife mitigation plan, High Ross wildlife mitigation study. Wash. Dep. Game under contract with Seattle City Light. 108 pp.

Kaster, J. L., and G. Z. Jacobi. 1978. Benthic macroinvertebrates of a fluctuating reservoir. Freshwater Biol. 8:283-290.

Kurko, K. W., S. J. Sweeney, and T. J. Juelson. 1980. Snohomish mediated plan wildlife study. Wash. Dep. Game under contract to U.S. Army Corps of Eng., Seattle, Washington. 173 pp.

Leopold, A. S. 1969. Adaptability of animals to habitat change. Pages 51-63 in G. W. Cox, ed. Readings in conservation ecology. Meredith Corp., New York. 595 pp.

Lindström, T. 1973. Life in a lake reservoir: fewer options, decreased production. Ambio 2:145-153.

Manning, H. 1978. Footsore 2. Walks and hikes around Puget Sound. The Mountaineers, Seattle, Washington. 224 pp.

McLachan, A. J. 1977. The changing role of terrestrial and autochthonous organic matter in newly flooded lakes. Hydrobiologia 53:215-217.

Meehan, W. R., F. J. Swanson, and J. R. Sedell. 1977. Influences of riparian vegetation in aquatic ecosystems with particular reference to salmonid fishes and their food supply in importance, preservation, and management of riparian habitat: a symposium. USDA For. Serv. Gen. Tech. Report RM-43. Pp. 137-145.

Mongillo, P., and L. Faulconer. 1980. Yakima fisheries enhancement study. Wash. State Dept. Game, Applied Wildl. Ecol., Olympia, WA. 171 pp.

Mundie, J. M. 1971. Sampling benthos and substrate materials down to 50 microns in size, in shallow streams. J. Fish. Res. Board Can. 28(6):849-860.

Nebecker, A. V. 1971. Effect of high winter water temperatures on adult emergence of aquatic insects. Water Resour. 5:777-783.

Nelson, R. W., G. C. Horak, and J. E. Olson. 1978. Western reservoir and stream habitat improvements handbook. Prepared for the Western Energy and Land Use Team, Office of Biological Services. Fish. Wildl. Serv., USDI. Contract No. 14-16-0008-2151 FWS, Western Water Allocation Project.

Nilsson, N. 1961. The effect of water-level fluctuations on the feeding habits of trout and char in the Lake Blasjon and Jormsjon, North Sweden. Inst. Freshwater Res. Drottningholm, Sweden. 42:238-261.

Olson, P. R. 1978. Existing bodies of water on the Cedar and Tolt River watersheds and their potential for fisheries production. Seattle Water Dept. Seattle, WA. 56 pp.

Pacific Northwest River Basins Commission. 1969. River mile index to the Deschutes, Nisqually, Puyallup, Green, Lake Washington, and Snohomish Rivers, Washington. Hydrology and hyrdraulics committee. 55 pp.

Paterson, C. G., and C. H. Fernando. 1969. The effect of winter drainage on reservoir benthic fauna. Can. J. Zool. 47:589-595.

Pennak, R. W. 1978. Freshwater invertebrates of the United States, Wiley and Sons, New York. 803 pp.

Reynolds, R. T., J. M. Scott, and R. A. Nussbaum. 1980. A variable circular-plot method for estimating bird numbers. Condor 82:309-313.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. No. 191. 382 pp.

Sawyer, R. T. 1970. North American freshwater leeches, exclusive of the Piscicolidae, with a key to all species. Ill. Biol. Monogr. 46:1-154.

Schoen, J. 1976. Rocky mountain elk and black-tailed deer inhabiting the Morse Lake basin. Appendix B in R. D. Taber, ed. Proposed alternatives in Morse Lake levels: impacts on wildlife habitats and populations. Coll. For. Resour., Univ. Washington, Seattle. 13 pp.

Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. Bull. 184. Fish. Res. Board Can. Ottawa, Ontario, Canada. 966 pp.

Slaney, F. F., and Company, Ltd. 1973. Environmental investigations, proposed High Ross Reservoir Vol. IV: Wildlife--avian resources and habitat development and improvement. City of Seattle Department of Lighting.

Spence, J. A., and H. B. N. Hynes. 1971. Differences in benthos upstream and downstream of an impoundment. J. Fish. Res. Board Can. 28:35-43.

Stober, Q. J., R. W. Tyler, C. E. Petrosky, K. R. Johnson, C. F. Cowman, J. Wilcock, and R. E. Nakatani. 1979. Development and evaluation of a net barrier to reduce entrainment loss of kokanee from Banks Lake. Fish. Res. Inst. Seattle, Washington. FRI-UW-7907. 246 pp.

Stockner, J. G., and K. R. Shortreed. 1978. Enhancement of autotrophic production by nutrient addition in a coastal rainforest stream on Vancouver Island. J. Fish. Res. Board Can. 35:28-34.

Swanson, F. J., and G. W. Lienkaemper. 1978. Physical consequences of large organic debris in Pacific Northwest streams. USDA For. Serv., Gen. Tech. Rep., PNW-69. 12 pp.

Swanson, F. J., and G. W. Lienkaemper, and J. R. Sedell. 1976. History, physical effects, and management implications of large organic debris in western Oregon streams. USDA For. Serv. Gen. Tech. Rep. PNW-56. 15 pp.

Sweeney, B. W. 1978. Bioenergetic and developmental response of a mayfly to thermal variation. Limnol. Oceanogr. 23:461-477.

Symons et al. 1964. Influence of impoundments on water quality. Publ. U.S. Pub. Health Serv. 99-WP-18. 78 pp.

Taber, R. D., and K. J. Raedeke. 1980. Black-tailed deer of the Olympic National Forest. Final Report to Olympic National Forest, U.S. For. Serv. Contract No. R6-79-237. Coll. For. Resour., Univ. Washington, Seattle. 90 pp.

Thomas, J. W. 1979. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. Agricultural handbook No. 533,

USDA For. Serv. published in cooperation with the Wildl. Mgmt. Inst. Washington, D.C., and the USDI Bureau of Land Management. 511 pp.

U.S. Army Corps of Engineers. 1968. Snoqualmie River, Washington, flood control and other improvements. Vol. 2. Seattle, Wash.

__________. 1976. Reconnaissance report on the mediated plan, Snohomish River basin, Washington. 33 pp.

__________. 1980a. North Fork Snoqualmie River water quality and temperature study. Seattle, Wash. 63 pp.

__________. 1980b. Dickey-Lincoln School Lakes Environmental Impact Statement. Appendix K: Fish Wildl. Mitigation plan. Waltham, Mass. 108 pp.

Ward, B. R., and P. A. Slaney. 1979. Evaluation of instream enhancement structures fc. the production of juvenile steelhead trout and coho salmon in the Keough River: progress 1977 and 1978. Fish. Tech. Circ. No. 45. Province of British Columbia Ministry Environment. Fish. Wildl. Branch. Victoria, B.C.

Ward, J. V. 1976a. Effects of flow patterns below large dams on stream benthos: a review. Pages 235-253 in J. F. Osborn and C. H. Allman, eds. Instream flow needs symposium. Vol. II. Amer. Fish. Soc. Bethesda, Maryland.

Ward, J. V. 1976b. Effects of thermal constancy and seasonal temperature displacement on community structure of stream macroinvertebrates. Pages 302-307 in G. W. Eschand and R. W. McFarlane, eds. Thermal ecology II. ERDA Symp. Ser. (CONF - 750425).

Ward, J. V., and J. A. Stanford. 1979. Ecological factors controlling stream zoobenthos with emphasis on thermal modification of regulated streams. Pages 35-55 in J. V. Ward and J. A. Stanford, eds. The ecology of regulated streams. Plenum Press, New York. 398 pp.

Washington State Department of Game. 1978. Big game status report, 1977-1978. Olympia. 311 pp.

__________. 1979. Big game status report, 1978-1979. Olympia. 241 pp.

__________. 1980. Streamside management zone inventory (Draft). Olympia.

__________. 1981. in prep (due April). Sultan River project--Stage III, fish and wildlife resource studies. Final report, under contract to Snohomish County Public Utility District.

Williams, R. W., R. M. Laramie, J. J. Ames. 1975. A catalog of Washington streams and salmon utilization. Vol. I. Puget Sound region. Washington Dept. Fish., Olympia, WA.

Wood, B., J. Powell, R. Ryno, and J. Tabor. 1980. Cowlitz Falls fish and wildlife study, annual report. Wash. State Dept. Game, Habitat Mgmt. Div., Applied Wildl. Ecol. Section. 164 pp.

Wydoski, R. S., and R. R. Whitney. 1979. Inland fishes of Washington. Univ. Washington Press, Seattle, Wash. 220 pp.

Wyman, K. H. Jr. 1975. Two unfished salmonid populations in Lake Chester Morse. M.S. Thesis, Univ. Washington, Seattle. 53 pp.

Zippin, C. 1958. The removal method of population estimation. J. Wildl. Mgmt. 22(1):82-91.

## Appendix A

List of species and other taxonomic groups.

Animals documented in North Fork Snoqualmie drainage during 1979 - 1980 field studies.

| Common name | Scientific name |
|---|---|
| **Benthos** | |
| mayflies | Ephemeroptera |
| --- | *Cinygmula* sp. |
| --- | *Epeorus* sp. |
| --- | *Baetis* sp. |
| --- | *Ephemerella* sp. |
| --- | *Ameletus* sp. |
| --- | *Rhithrogena* sp. |
| stoneflies | Plecoptera |
| --- | unid. Chloroperlidae |
| --- | *Alloperla* sp. |
| --- | *Acroneuria* sp. |
| caddisflies | Tricoptera |
| --- | *Glossosoma* sp. |
| --- | *Hydropsyche* sp. |
| --- | *Brachycentrus* sp. |
| --- | *Ryacophila* sp. |
| --- | *Himalopsyche* sp. |
| --- | unid. Odentoceridae |
| --- | unid. Hydropsychidae |
| --- | *Psychoglypha* sp. |
| dragonflies and damselflies | Odonata |
| flies | Diptera |
| midges | Chironomidae |
| crane flies | Tipulidae |
| --- | *Antocha* sp. |
| --- | *Tipula* sp. |
| --- | *Hexatoma* sp. |
| --- | *Hesperoconopa* sp. |
| snipe fly | *Atherix variegata* |
| no-see-ums | Ceratopogonidae |
| --- | *Palpolyia*/*Bezzia*/*Frobezzia* sp. |

| Common name | Scientific name |
|---|---|
| **Benthos - cont'd** | |
| black flies | Simulidae |
| --- | *Simulium* sp. |
| tree bugs | Hemiptera |
| giant water bugs | Belostomatidae |
| --- | *Lethocerus americanus* |
| beetles | Coleoptera |
| --- | *Narpus* sp. |
| --- | unid. carabidae |
| springtails | Collembola |
| --- | unid. Sminthuridae |
| aquatic earthworms | Oligochaeta |
| leeches | Hirudinea |
| clams and mussels | Pelecypoda |
| clams | Sphaeridae |
| **Fish** | |
| cutthroat trout | *Salmo clarki* |
| rainbow trout | *Salmo gairdneri* |
| brook trout | *Salvelinus fontinalis* |
| mountain whitefish | *Prosopium williamsoni* |
| shorthead sculpin | *Cottus confusus* |
| mottled sculpin | *Cottus bairdi* |
| largescale suckers | *Catostomus macrocheilus* |
| longnose dace | *Rhinichthys cataractae* |
| **Amphibians and Reptiles** | |
| northwestern salamander | *Ambystoma gracile* |
| Pacific giant salamander | *Dicamptodon ensatus* |
| rough-skinned newt | *Taricha granulosa* |
| tailed frog | *Ascaphus truei* |
| western toad | *Bufo boreas* |
| Pacific treefrog | *Hyla regilla* |
| red-legged frog | *Rana aurora* |
| northern alligator lizard | *Gerrhonotus coeruleus* |
| common garter snake | *Thamnophis sirtalis* |
| northwestern garter snake | *Thamnophis ordinoides* |

| Common name | Scientific name |
|---|---|
| **Birds** | |
| Common Loon | Gavia immer |
| Pied-billed Grebe | Podilymbus podiceps |
| Great Blue Heron | Ardea herodias |
| Swan | Olor sp. |
| Mallard | Anas platyrhynchos |
| Pintail | Anas acuta |
| Green-winged Teal | Anas crecca |
| American Wigeon | Anas americana |
| Wood Duck | Aix sponsa |
| Ring-necked Duck | Aythya collaris |
| Common Goldeneye | Bucephala clangula |
| Harlequin Duck | Histrionicus histrionicus |
| Hooded Merganser | Lophodytes cucullatus |
| Common Merganser | Mergus merganser |
| Goshawk | Accipiter gentilis |
| Sharp-shinned Hawk | Accipiter striatus |
| Cooper's Hawk | Accipiter cooperii |
| Red-tailed Hawk | Buteo jamaicensis |
| Golden Eagle | Aquila chrysaetos |
| Bald Eagle | Haliaeetus leucocephalus |
| Marsh Hawk | Circus cyaneus |
| Osprey | Pandion haliaetus |
| American Kestrel | Falco sparverius |
| Blue Grouse | Dendragapus obscurus |
| Ruffed Grouse | Bonasa umbellus |
| California Quail | Lophortyx californicus |
| Spotted Sandpiper | Actitis macularia |
| Band-tailed Pigeon | Columba fasciata |
| Screech Owl | Otus asio |
| Pygmy Owl | Glaucidium gnoma |
| Saw-whet Owl | Aegolius acadicus |
| Common Nighthawk | Chordeiles minor |
| Black Swift | Cypseloides niger |
| Vaux's Swift | Chaetura vauxi |
| Rufous Hummingbird | Selasphorus rufus |
| Belted Kingfisher | Megaceryle alcyon |
| Common Flicker | Colaptes auratus |
| Pileated Woodpecker | Dryocopus pileatus |
| Red-breasted Sapsucker | Sphyrapicus ruber |
| Hairy Woodpecker | Dendrocopus villosus |
| Downy Woodpecker | Dendrocopus pubescens |
| Eastern Kingbird | Tyrannus tyrannus |
| Willow Flycatcher | Empidonax traillii |

| Common name | Scientific name |
|---|---|
| **Birds - cont'd** | |
| Hammond's Flycatcher | Empidonax hammondii |
| Western Flycatcher | Empidonax difficilis |
| Olive-sided Flycatcher | Nuttallornis borealis |
| Horned Lark | Eremophila alpestris |
| Tree Swallow | Iridoprocne bicolor |
| Rough-winged Swallow | Stelgidopteryx ruficollis |
| Gray Jay | Perisoreus canadensis |
| Steller's Jay | Cyanocitta stelleri |
| Common Raven | Corvus corax |
| Common Crow | Corvus brachyrhynchos |
| Black-capped Chickadee | Parus atricapillus |
| Chestnut-backed Chickadee | Parus rufescens |
| Bushtit | Psaltriparus minimus |
| Red-breasted Nuthatch | Sitta canadensis |
| Brown Creeper | Certhia familiaris |
| Dipper | Cinclus mexicanus |
| Winter Wren | Troglodytes troglodytes |
| Bewick's Wren | Thryomanes bewickii |
| Long-billed Marsh Wren | Telmatodytes palustris |
| American Robin | Turdus migratorius |
| Varied Thrush | Ixoreus naevius |
| Hermit Thrush | Catharus guttatus |
| Swainson's Thrush | Catharus ustulatus |
| Mountain Bluebird | Sialia currucoides |
| Townsend's Solitaire | Myadestes townsendi |
| Golden-crowned Kinglet | Regulus satrapa |
| Ruby-crowned Kinglet | Regulus calendula |
| Cedar Waxwing | Bombycilla cedrorum |
| Starling | Sturnus vulgaris |
| Hutton's Vireo | Vireo huttoni |
| Warbling Vireo | Vireo gilvus |
| Orange-crowned Warbler | Vermivora celata |
| Yellow Warbler | Dendroica petechia |
| Yellow-rumped Warbler | Dendroica coronata |
| Black-throated Gray Warbler | Dendroica nigrescens |
| Townsend's Warbler | Dendroica townsedi |
| Hermit Warbler | Dendroica occidentalis |
| MacGillivray's Warbler | Oporornis tolmiei |
| Common Yellowthroat | Geothlypis trichas |
| Wilson's Warbler | Wilsonia pusilla |
| Red-winged Blackbird | Agelaius phoeniceus |
| Western Tanager | Piranga ludoviciana |
| Black-headed Grosbeak | Pheucticus melanocephalus |

| Common name | Scientific name |
|---|---|
| **Birds** - cont'd | |
| Evening Grosbeak | Hesperiphona vespertina |
| Purple Finch | Carpodacus purpureus |
| Pine Grosbeak | Pinicola enucleator |
| Pine Siskin | Spinus pinus |
| American Goldfinch | Spinus tristis |
| Rufous-sided Towhee | Pipilo erythrophthalmus |
| Dark-eyed Junco | Junco hyemalis |
| White-crowned Sparrow | Zonotrichia leucophrys |
| Golden-crowned Sparrow | Zonotrichia atricapilla |
| Fox Sparrow | Passerella iliaca |
| Song Sparrow | Melospiza melodia |
| **Mammals** | |
| vagrant shrew | Sorex vagrans |
| dusky shrew | Sorex obscurus |
| Trowbridge's shrew | Sorex trowbridgii |
| coast mole | Scapanus orarius |
| big brown bat | Eptesicus fuscus |
| pika | Ochotona princeps |
| snowshoe hare | Lepus americanus |
| mountain beaver | Aplodontia rufa |
| Townsend's chipmunk | Eutamias townsendii |
| Douglas' squirrel | Tamiasciurus douglasii |
| beaver | Castor canadensis |
| deer mouse | Peromyscus maniculatus |
| Gapper's Red-backed mouse | Clethrionomys gapperi |
| Townsend's vole | Microtus townsendii |
| long-tailed vole | Microtus longicaudus |
| creeping vole | Microtus oregoni |
| muskrat | Ondatra zibethicus |
| Pacific jumping mouse | Zapus trinotatus |
| porcupine | Erethizon dorsatum |
| coyote | Canis latrans |
| black bear | Ursus americanus |
| ermine | Mustela erminea |
| long-tailed weasel | Mustela frenata |
| mink | Mustela vison |
| river otter | Lutra canadensis |
| cougar* | Felis concolor |
| bobcat | Lynx rufus |
| Black-tailed deer | Odocoileus hemionus columbianus |
| mountain goat | Oreamnos americanus |

*Observed by reliable outside source.

Animals mentioned in text but not found during study.

| Common name | Scientific name |
|---|---|
| fish tapeworm | Diphyllobothrium sp. |
| water boatmen | Corixidae |
| scuds and sideswimmers (shrimp) | Amphipoda |
| steelhead | Salmo gairdneri |
| brown trout | Salmo trutta |
| Dolly Varden trout | Salvelinus malma |
| chinook salmon | Oncorhynchus tshawytscha |
| coho salmon | Oncorhynchus kisutch |
| kokanee | Oncorhynchus nerka |
| torrent sculpin | Cottus rhotheus |
| bufflehead | Bucephala albeola |
| spotted owl | Strix occidentalis |
| white-tailed deer | Odocoileus virginianus |

## Appendix B

Species, number, and size of fish caught in Howard Hanson Reservoir.

Species, number, and size of fish caught in gillnets in Howard Hanson Reservoir on 17 July 1980. The Reservoir's pool was full.

| Species | N | Mean length (mm) | Length range (mm) | Mean weight (g) | Weight range (g) |
|---|---|---|---|---|---|
| rainbow trout | 10 | 260 | 178-415 | 255 | 78-708 |
| cutthroat trout | 10 | 251 | 180-330 | 225 | 70-450 |
| mountain whitefish | 9 | 234 | 204-325 | 177 | 107-442 |
| brook trout | 1 | 282 | - | 365 | - |
| torrent sculpin (*Cottus rhotheus*) | 1 | 128 | - | 29 | - |

Appendix C

Instream flow tables.

# Station 1

## Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR RAINBOW TROUT

| Q | FRY | JUVENILES | ADULT | SPAWNING | INCUBATION |
|---|---|---|---|---|---|
| 30.00 | 1849.32 | 2432.84 | 5976.29 | 841.67 | 6859.79 |
| 40.00 | 3265.93 | 3182.99 | 7770.88 | 951.12 | 9869.42 |
| 50.00 | 4128.53 | 4388.59 | 9484.24 | 1172.25 | 13609.12 |
| 60.00 | 6580.08 | 6038.00 | 11018.21 | 1890.37 | 17136.75 |
| 70.00 | 9511.44 | 7823.83 | 12558.71 | 2717.24 | 20317.16 |
| 80.00 | 12030.00 | 10217.38 | 13823.67 | 3710.71 | 23248.45 |
| 90.00 | 12832.90 | 13309.27 | 15232.98 | 4350.19 | 25764.37 |
| 100.00 | 14203.21 | 16691.37 | 16774.96 | 4998.76 | 27926.08 |
| 110.00 | 16083.97 | 19440.94 | 18086.96 | 5544.51 | 29944.27 |
| 120.00 | 16210.21 | 21038.62 | 19368.98 | 5912.61 | 31746.62 |
| 130.00 | 16206.10 | 21821.00 | 20599.63 | 6273.85 | 33420.97 |
| 140.00 | 15807.32 | 22776.40 | 22018.93 | 6697.85 | 35001.04 |
| 150.00 | 15309.68 | 23678.13 | 23534.81 | 6979.84 | 36401.44 |
| 160.00 | 14764.80 | 24079.71 | 25077.00 | 7255.23 | 37698.94 |
| 170.00 | 14062.55 | 23765.09 | 26736.11 | 7354.03 | 38832.32 |
| 180.00 | 13275.86 | 23165.78 | 28164.12 | 7292.00 | 39849.58 |
| 190.00 | 12512.71 | 22329.67 | 29397.50 | 7211.00 | 40678.77 |
| 200.00 | 11794.40 | 21394.84 | 30566.16 | 7099.20 | 41370.76 |
| 210.00 | 11158.23 | 20377.74 | 31723.16 | 6934.40 | 42001.16 |
| 220.00 | 10496.42 | 19356.33 | 32800.70 | 6675.31 | 42452.28 |
| 230.00 | 9898.81 | 18484.07 | 33928.08 | 6405.98 | 42830.06 |
| 240.00 | 9315.01 | 17706.52 | 34955.17 | 6110.96 | 43182.11 |
| 250.00 | 8729.97 | 16644.88 | 35775.15 | 5795.99 | 43448.34 |
| 260.00 | 8291.12 | 16071.89 | 36624.68 | 5493.32 | 43693.35 |
| 270.00 | 8058.97 | 15347.04 | 37441.10 | 5201.86 | 43921.44 |
| 280.00 | 7852.30 | 14615.83 | 38288.92 | 4936.63 | 44124.48 |
| 290.00 | 7640.52 | 13886.42 | 39163.45 | 4663.42 | 44286.45 |
| 300.00 | 7273.65 | 13151.43 | 39952.32 | 4397.65 | 44420.18 |
| 310.00 | 6866.65 | 12458.01 | 40698.14 | 4126.99 | 44540.58 |
| 320.00 | 6512.16 | 11928.14 | 41220.86 | 3877.66 | 44617.37 |
| 330.00 | 6196.21 | 11516.81 | 41489.93 | 3651.20 | 44652.84 |
| 340.00 | 5909.25 | 11126.41 | 41607.05 | 3457.40 | 44672.40 |
| 350.00 | 5658.00 | 10746.22 | 41518.30 | 3295.31 | 44883.11 |
| 360.00 | 5446.60 | 10382.71 | 41338.07 | 3143.97 | 44871.95 |
| 370.00 | 5259.15 | 10026.94 | 41183.69 | 3016.15 | 44644.44 |
| 380.00 | 5098.28 | 9721.42 | 40943.08 | 2915.21 | 44570.59 |
| 390.00 | 4959.87 | 9397.49 | 40845.77 | 2835.36 | 44499.68 |
| 400.00 | 4825.66 | 8983.81 | 40705.30 | 2759.69 | 44415.86 |

# STATION 1

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET
OF STREAM FOR RAINBOW TROUT

| Q | FRY | JUVENILES | ADULT | SPAWNING | INCUBATION |
|---|---|---|---|---|---|
| 410.00 | 4683.28 | 8678.98 | 40521.13 | 2701.47 | 44321.09 |
| 420.00 | 4540.19 | 8445.33 | 40373.76 | 2653.58 | 44196.23 |
| 430.00 | 4424.34 | 8261.30 | 40196.11 | 2614.93 | 44024.24 |
| 440.00 | 4361.05 | 8075.44 | 39814.44 | 2594.46 | 43827.48 |
| 450.00 | 4300.96 | 7888.63 | 39439.07 | 2577.76 | 43600.[illegible] |
| 460.00 | 4270.50 | 7733.49 | 39072.45 | 2553.75 | 43357.05 |
| 470.00 | 4243.53 | 7634.72 | 38738.01 | 2541.39 | 43077.49 |
| 480.00 | 4181.54 | 7516.93 | 38457.67 | 2527.07 | 42770.56 |
| 490.00 | 4052.05 | 7396.70 | 38102.56 | 2500.68 | 42413.00 |
| 500.00 | 3928.33 | 7316.03 | 37734.53 | 2477.77 | 42032.22 |
| 510.00 | 3815.68 | 7234.79 | 37355.01 | 2455.97 | 41658.53 |
| 520.00 | 3720.47 | 7147.27 | 36976.76 | 2417.1[illegible] | 41297.03 |
| 530.00 | 3626.88 | 7062.26 | 36601.58 | 2365.95 | 40926.60 |
| 540.00 | 3557.87 | 6989.57 | 36246.79 | 2321.19 | 40544.19 |
| 550.00 | 3516.42 | 6924.77 | 35869.01 | 2275.61 | 40145.80 |
| 560.00 | 3482.30 | 6877.16 | 35505.60 | 2232.05 | 39729.64 |
| 570.00 | 3455.28 | 6830.83 | 35124.39 | 2190.15 | 39301.60 |
| 580.00 | 3427.99 | 6782.29 | 34714.78 | 2149.77 | 38871.61 |
| 590.00 | 3399.57 | 6729.50 | 34323.44 | 2110.75 | 38425.43 |
| 600.00 | 3346.69 | 6654.70 | 33957.68 | 2070.95 | 37964.63 |
| 610.00 | 3263.64 | 6554.05 | 33594.72 | 2032.38 | 37504.30 |
| 620.00 | 3184.24 | 6475.21 | 33225.25 | 1997.60 | 37041.37 |
| 630.00 | 3107.59 | 6400.75 | 32864.53 | 1965.09 | 36602.96 |
| 640.00 | 3036.91 | 6331.14 | 32552.89 | 1937.23 | 36144.70 |
| 650.00 | 2968.48 | 6265.31 | 32237.61 | 1911.[illegible] | 35739.40 |
| 660.00 | 2901.62 | 6203.44 | 31990.94 | 1885.46 | 35314.44 |
| 670.00 | 2841.10 | 6188.15 | 31746.[illegible]3 | 1859.51 | [illegible]4928.56 |
| 680.00 | 2785.05 | 6134.66 | 21496.23 | 1833.11 | 24565.92 |
| 690.00 | 2729.45 | 6099.80 | 31248.13 | 1805.23 | 39207.02 |
| 700.00 | 2678.60 | 6064.98 | 31003.30 | 1777.10 | 33851.22 |
| 710.00 | 2623.42 | 6043.10 | 30773.42 | 1750.71 | 33490.15 |
| 720.00 | 2570.90 | 6023.74 | 30531.66 | 1724.04 | 33157.52 |
| 730.00 | 2519.39 | 6005.18 | 30337.51 | 1696.91 | 32827.82 |
| 740.00 | 2465.59 | 5955.78 | [illegible]0128.20 | 1671.53 | 32501.34 |
| 750.00 | 2410.98 | 5891.08 | 29920.13 | 1649.95 | 32180.14 |
| 760.00 | 2358.42 | 5828.02 | 29710.91 | 1628.28 | 31863.68 |
| 770.00 | 2307.12 | 5768.05 | 29490.86 | 1606.28 | 31565.12 |
| 780.00 | 2258.22 | 5697.58 | 29298.52 | 1582.19 | 31261.66 |
| 790.00 | 2212.32 | 5627.66 | 29100.27 | 1557.46 | 30962.25 |
| 800.00 | 2167.73 | 5558.99 | 28902.96 | 1532.29 | 30678.20 |

# Station 1

Q. VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR MOUNTAIN WHITEFISH

| Q | FRY | JUVENILE | ADULT | SPAWNING |
|---|---|---|---|---|
| 30.00 | 3643. | 7152.77 | 6969.20 | 2824.78 |
| 40.00 | 3653. | 7975.26 | 7322.60 | 3865.30 |
| 50.00 | 3668. | 9347.09 | 7707.71 | 5546.52 |
| 60.00 | 3608. | 10686.32 | 8139.72 | 8121.18 |
| 70.00 | 3605. | 12871.88 | 8742.10 | 9916.73 |
| 80.00 | 3646. | 15500.40 | 9368.89 | 11862.85 |
| 90.00 | 3518. | 19259.75 | 9835.61 | 14189.04 |
| 100.00 | 3581.93 | 23498.27 | 10350.30 | 18066.38 |
| 110.00 | 3710.72 | 27431.28 | 10864.29 | 22065.21 |
| 120.00 | 3785.52 | 30137.62 | 11328.35 | 25552.75 |
| 130.00 | 3819.29 | 32584.86 | 11795.59 | 27675.07 |
| 140.00 | 3930.05 | 34756.53 | 12265.28 | 29516.47 |
| 150.00 | 4043.39 | 36279.97 | 12754.05 | 31380.19 |
| 160.00 | 4127.41 | 37333.54 | 13272.26 | 33173.43 |
| 170.00 | 4188.82 | 37914.29 | 13806.49 | 34453.33 |
| 180.00 | 4250.37 | 38016.71 | 14402.77 | 35735.80 |
| 190.00 | 4327.09 | 37644.30 | 15057.33 | 36596.50 |
| 200.00 | 4411.22 | 37284.47 | 15741.19 | 37203.43 |
| 210.00 | 4483.38 | 36433.97 | 16473.80 | 37474.26 |
| 220.00 | 4559.81 | 35624.57 | 17279.00 | 37602.57 |
| 230.00 | 4629.76 | 34792.28 | 18122.91 | 37448.30 |
| 240.00 | 4683.91 | 33754.50 | 18971.73 | 37143.43 |
| 250.00 | 4732.62 | 33133.53 | 19828.26 | 36709.57 |
| 260.00 | 4760.24 | 32410.21 | 20700.50 | 36102.66 |
| 270.00 | 4783.73 | 31683.50 | 21554.24 | 35319.80 |
| 280.00 | 4804.72 | 31035.98 | 22408.76 | 34484.26 |
| 290.00 | 4828.52 | 30442.62 | 23290.85 | 33824.91 |
| 300.00 | 4848.91 | 30005.07 | 24129.75 | 33251.84 |
| 310.00 | 4871.14 | 29605.10 | 24978.53 | 32557.61 |
| 320.00 | 4913.26 | 29327.93 | 25822.56 | 31802.87 |
| 330.00 | 4962.60 | 29080.86 | 26612.80 | 31088.92 |
| 340.00 | 5002.21 | 28944.27 | 27358.40 | 30396.64 |
| 350.00 | 5052.31 | 28882.92 | 28008.99 | 29746.94 |
| 360.00 | 5101.60 | 28835.82 | 28604.04 | 29144.35 |
| 370.00 | 5150.08 | 28782.81 | 29174.48 | 28595.45 |
| 380.00 | 5190.67 | 28784.44 | 29718.81 | 28064.66 |
| 390.00 | 5230.06 | 28717.76 | 30238.73 | 27557.06 |
| 400.00 | 5297.99 | 28632.63 | 30149.81 | 27029.06 |

# STATION 1

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET
OF STREAM FOR MOUNTAIN WHITEFISH

| Q | FRY | JUVENILE | ADULT | SPAWNING |
|---|---|---|---|---|
| 410.00 | 5379.19 | 28493.75 | 31194.60 | 26470.69 |
| 420.00 | 5458.29 | 28322.98 | 31550.46 | 25978.35 |
| 430.00 | 5522.01 | 28142.91 | 31808.21 | 25374.35 |
| 440.00 | 5581.49 | 27949.09 | 31966.78 | 24836.67 |
| 450.00 | 5638.16 | 27757.92 | 31836.20 | 24494.24 |
| 460.00 | 5692.78 | 27558.82 | 31901.44 | 24086.91 |
| 470.00 | 5720.92 | 27344.64 | 32065.50 | 23733.21 |
| 480.00 | 5745.02 | 27136.00 | 32166.00 | 23419.28 |
| 490.00 | 5770.45 | 26889.68 | 32285.08 | 23163.82 |
| 500.00 | 5782.43 | 26607.18 | 32445.03 | 22952.79 |
| 510.00 | 5795.05 | 26322.27 | 32596.12 | 22735.29 |
| 520.00 | 5820.62 | 26037.55 | 32705.26 | 22625.93 |
| 530.00 | 5844.61 | 25772.10 | 32783.53 | 22458.85 |
| 540.00 | 5864.86 | 25535.76 | 32929.80 | 22274.51 |
| 550.00 | 5869.67 | 25306.97 | 33062.37 | 22130.70 |
| 560.00 | 5868.92 | 25061.15 | 33198.46 | 22023.35 |
| 570.00 | 5882.33 | 24851.66 | 33300.37 | 21936.14 |
| 580.00 | 5884.28 | 24631.99 | 33418.76 | 21882.77 |
| 590.00 | 5891.31 | 24406.79 | 33501.75 | 21825.93 |
| 600.00 | 5894.69 | 24193.06 | 33479.67 | 21751.62 |
| 610.00 | 5886.67 | 24005.25 | 33445.50 | 21647.64 |
| 620.00 | 5886.60 | 23811.36 | 33417.86 | 21541.36 |
| 630.00 | 5888.47 | 23681.06 | 33428.84 | 21451.40 |
| 640.00 | 5884.78 | 23529.15 | 33448.57 | 21372.60 |
| 650.00 | 5872.14 | 23353.23 | 33446.77 | 21310.44 |
| 660.00 | 5854.49 | 23217.73 | 33514.02 | 21231.09 |
| 670.00 | 5847.84 | 23163.70 | 33516.96 | 21165.46 |
| 680.00 | 5849.02 | 23127.50 | 33500.80 | 21101.90 |
| 690.00 | 5851.49 | 23069.30 | 33474.45 | 21030.43 |
| 700.00 | 5870.32 | 22999.77 | 33425.22 | 20989.67 |
| 710.00 | 5877.44 | 228[illegible] | 33304.59 | 21020.57 |
| 720.00 | 5885.93 | [illegible] | 33384.62 | 21063.01 |
| 730.00 | 5903.66 | [illegible] | 33333.37 | 21119.69 |
| 740.00 | 5918.73 | [illegible] | 33258.02 | 21098.01 |
| 750.00 | 5969.95 | [illegible] | [illegible] | 21041.29 |
| 760.00 | 5932.44 | [illegible] | [illegible] | 20987.72 |
| 770.00 | 5917.16 | [illegible] | [illegible] | 20940.08 |
| 780.00 | 5867.00 | [illegible] | [illegible] | 20863.86 |
| 790.00 | 5854.36 | [illegible] | [illegible] | 20791.19 |
| 800.00 | 5822.20 | 21473.84 | 32570.28 | 20719.69 |

# Station 2

Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR RAINBOW TROUT

| Q | FRY | JUVENILES | ADULT | SPAWNING | INCUBATION |
|---|---|---|---|---|---|
| 10.00 | 2369.93 | 727.95 | 2124.79 | 0.00 | 1922.56 |
| 20.00 | 5526.96 | 2002.15 | 2149.30 | 1282.89 | 5132.07 |
| 30.00 | 8264.16 | 4395.14 | 2910.26 | 4302.18 | 7149.25 |
| 40.00 | 9806.93 | 7169.52 | 3693.70 | 5408.57 | 8857.36 |
| 50.00 | 9840.00 | 10557.73 | 4466.05 | 5737.31 | 10674.84 |
| 60.00 | 10003.96 | 12212.92 | 5599.74 | 6150.29 | 12435.43 |
| 70.00 | 10166.23 | 12592.61 | 6914.22 | 6758.35 | 14251.61 |
| 80.00 | 11039.14 | 13340.59 | 8444.16 | 7305.25 | 16294.41 |
| 90.00 | 12485.83 | 14456.95 | 10444.63 | 7561.56 | 18019.26 |
| 100.00 | 13150.01 | 15327.22 | 12607.84 | 7725.25 | 19698.25 |
| 110.00 | 12825.76 | 15960.62 | 14652.54 | 7813.35 | 21369.74 |
| 120.00 | 12679.12 | 16684.47 | 16676.45 | 7827.96 | 22873.25 |
| 130.00 | 12715.77 | 17340.08 | 18521.58 | 7951.22 | 24182.47 |
| 140.00 | 13196.89 | 17954.88 | 20335.05 | 8027.26 | 25344.65 |
| 150.00 | 13312.54 | 18425.84 | 21929.53 | 7992.31 | 26469.88 |
| 160.00 | 13169.59 | 18553.40 | 23572.78 | 7972.98 | 27532.90 |
| 170.00 | 12830.87 | 18785.11 | 25424.79 | 7847.91 | 28511.60 |
| 180.00 | 12556.40 | 18958.63 | 27285.47 | 7709.51 | 29484.70 |
| 190.00 | 12167.80 | 19075.39 | 28979.24 | 7634.48 | 30422.38 |
| 200.00 | 11618.86 | 19204.47 | 30554.42 | 7481.14 | 31291.78 |
| 210.00 | 11035.66 | 19100.08 | 32249.74 | 7282.88 | 32054.20 |
| 220.00 | 10503.89 | 18847.29 | 33480.16 | 7034.42 | 32702.97 |
| 230.00 | 10031.13 | 18447.78 | 34111.20 | 6763.10 | 33219.49 |
| 240.00 | 9619.19 | 17940.70 | 34399.32 | 6529.26 | 33684.43 |
| 250.00 | 9234.52 | 17450.71 | 34292.03 | 6368.51 | 34156.17 |
| 260.00 | 8858.10 | 16769.31 | 33933.30 | 6284.72 | 34511.95 |
| 270.00 | 8495.07 | 16197.42 | 33599.04 | 6248.77 | 34815.22 |
| 280.00 | 8153.27 | 15703.69 | 33197.50 | 6250.33 | 35091.75 |
| 290.00 | 7647.58 | 15228.39 | 32872.34 | 6174.29 | 35364.50 |
| 300.00 | 7625.44 | 14814.36 | 32706.05 | 6120.88 | 35610.35 |
| 310.00 | 7396.39 | 14423.56 | 32513.91 | 6048.64 | 35811.69 |
| 320.00 | 7262.92 | 14089.17 | 32276.25 | 5978.53 | 35949.74 |
| 330.00 | 7126.73 | 13585.01 | 31846.11 | 5908.74 | 36023.44 |
| 340.00 | 7057.14 | 13055.89 | 31072.76 | 5771.06 | 36004.37 |
| 350.00 | 7069.47 | 12775.31 | 30661.31 | 5626.52 | 35896.73 |
| 360.00 | 6945.42 | 12555.22 | 32229.29 | 5432.79 | 35689.97 |

# STATION 2

## Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR RAINBOW TROUT

| Q | FRY | JUVENILES | ADULT | SPAWNING | INCUBATION |
|---|---|---|---|---|---|
| 370.00 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 380.00 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 390.00 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

# Station 3

~~Q VS. AVAILABLE HABITAT AREA PER 1000 FEET OF STREAM FOR CUTTHROAT TROUT~~

| Q | FRY | JUVENILE | ADULTS | SPAWNING | INCUBATION |
|---|---|---|---|---|---|
| 10.00 | 1869.74 | 946.59 | 1461.12 | 2.33 | 1791.13 |
| ~~20.00~~ | ~~8411.[illegible]~~ | ~~[illegible]~~ | ~~6456.61~~ | ~~242.24~~ | ~~4229.21~~ |
| 30.00 | 14681.40 | 10782.10 | 105[illegible].24 | 727.51 | 7767.77 |
| ~~40.00~~ | ~~15649.24~~ | ~~15486.40~~ | ~~13[illegible].47~~ | ~~1636.74~~ | ~~10402.25~~ |
| 50.00 | 15372.13 | 17917.57 | 16492.05 | 2174.54 | 14237.93 |
| ~~60.00~~ | ~~14697.11~~ | ~~19456.21~~ | ~~18411.43~~ | ~~2701.40~~ | ~~18055.69~~ |
| 70.00 | 13772.27 | 20594.53 | 20182.79 | 3133.31 | 21679.81 |
| ~~80.00~~ | ~~12638.42~~ | ~~21466.50~~ | ~~21601.46~~ | ~~3522.67~~ | ~~24665.65~~ |
| 90.00 | 11338.49 | 21748.07 | 22810.54 | 3605.25 | 29029.91 |
| ~~100.00~~ | ~~10159.37~~ | ~~21844.41~~ | ~~23341.44~~ | ~~4142.09~~ | ~~30790.95~~ |
| 110.00 | 9121.49 | 21618.43 | 23674.26 | 4427.68 | 33164.11 |
| ~~120.00~~ | ~~8188.61~~ | ~~21120.30~~ | ~~23825.19~~ | ~~4551.27~~ | ~~35220.25~~ |
| 130.00 | 7376.75 | 20522.85 | 24095.47 | 4627.44 | 37027.98 |
| ~~140.00~~ | ~~6687.12~~ | ~~19906.43~~ | ~~24315.16~~ | ~~4641.16~~ | ~~38623.26~~ |
| 150.00 | 6053.16 | 19233.21 | 24761.71 | 4609.14 | 39955.46 |
| ~~160.00~~ | ~~5494.23~~ | ~~18412.43~~ | ~~25252.61~~ | ~~4502.22~~ | ~~41078.40~~ |
| 170.00 | 4992.76 | 17553.24 | 25556.35 | 4392.76 | 41987.73 |
| ~~180.00~~ | ~~4557.44~~ | ~~16632.26~~ | ~~24915.47~~ | ~~4034.28~~ | ~~42738.71~~ |
| 190.00 | 4137.63 | 15484.71 | 24692.34 | 3744.75 | 43297.01 |
| ~~200.00~~ | ~~3822.13~~ | ~~14132.64~~ | ~~23828.13~~ | ~~3554.47~~ | ~~43762.46~~ |
| 210.00 | 3524.56 | 12715.52 | 22819.89 | 3465.77 | 43[illegible].63 |
| ~~220.00~~ | ~~3255.74~~ | ~~11122.13~~ | ~~21824.12~~ | ~~3422.66~~ | ~~43[illegible]~~ |
| 230.00 | 3012.49 | 9709.48 | 20682.75 | 3381.59 | 43[illegible]7.44 |
| ~~240.00~~ | ~~2803.14~~ | ~~8454.78~~ | ~~19229.07~~ | ~~3320.83~~ | ~~44623.71~~ |
| 250.00 | 2617.69 | 7[illegible] | 17554.42 | [illegible] | [illegible] |
| 260.00 | 2466.22 | 6[illegible] | 1605[illegible] | 30[illegible].68 | [illegible] |
| 270.00 | 2357.19 | [illegible] | 14515.67 | 2925.21 | [illegible] |
| 280.00 | [illegible]8[illegible].81 | [illegible] | [illegible] | 8[illegible] | [illegible] |
| 290.00 | 221[illegible].78 | [illegible] | [illegible]1.[illegible]2 | [illegible]78[illegible] | [illegible] |
| 300.00 | 150.86 | [illegible] | [illegible]00.[illegible] | [illegible]3[illegible] | [illegible] |
| 310.00 | 211[illegible].11 | [illegible] | 8678.05 | [illegible] | [illegible] |
| 320.00 | [illegible]066.32 | [illegible] | 7515.88 | [illegible]6[illegible] | [illegible] |
| 330.00 | 2003.[illegible] | [illegible]6[illegible] | [illegible]972.62 | [illegible]6[illegible] | [illegible] |
| [illegible]40.00 | 1959.35 | [illegible] | 61[illegible].75 | 25[illegible] | [illegible] |
| 350.00 | 1919.05 | [illegible] | 5480.52 | 253[illegible] | [illegible]8 |

Station 1

Q VS. AVAILABLE HABITAT AREA AS A PERCENTAGE
OF THE GROSS AREA FOR RAINBOW TROUT

| Q | GROSS | FRY | JUVENILES | ADULT | SPAWNING | INCUBATION |
|---|---|---|---|---|---|---|
| 20. | 57103. | 2.43 | 3.31 | 7.12 | 1.19 | 7.65 |
| 30. | 74310. | 2.49 | 3.27 | 8.04 | 1.13 | 9.23 |
| 40. | 80715. | 4.05 | 3.94 | 9.63 | 1.18 | 12.23 |
| 50. | 84254. | 5.61 | 5.21 | 11.26 | 1.39 | 16.15 |
| 60. | 86388. | 7.62 | 6.99 | 12.75 | 1.96 | 19.84 |
| 70. | 87916. | 10.82 | 8.90 | 14.28 | 3.09 | 23.11 |
| 80. | 89055. | 13.51 | 11.47 | 15.52 | 4.17 | 26.11 |
| 90. | 90038. | 14.25 | 14.78 | 16.92 | 4.83 | 28.61 |
| 100. | 90588. | 15.68 | 18.43 | 18.52 | 5.52 | 30.83 |
| 110. | 91103. | 17.65 | 21.34 | 19.85 | 6.09 | 32.87 |
| 120. | 91588. | 17.70 | 22.97 | 21.15 | 6.46 | 34.66 |
| 130. | 94177. | 17.21 | 23.17 | 21.87 | 6.66 | 35.49 |
| 140. | 94844. | 16.67 | 24.01 | 23.22 | 7.06 | 36.90 |
| 150. | 95331. | 16.06 | 24.64 | 24.69 | 7.32 | 38.18 |
| 160. | 95797. | 15.41 | 25.14 | 26.18 | 7.57 | 39.35 |
| 170. | 96244. | 14.61 | 24.69 | 27.78 | 7.64 | 40.25 |
| 180. | 97458. | 13.62 | 23.77 | 28.90 | 7.48 | 40.89 |
| 190. | 97826. | 12.79 | 22.83 | 30.05 | 7.37 | 41.58 |
| 200. | 98331. | 11.99 | 21.76 | 31.11 | 7.22 | 42.07 |
| 210. | 98904. | 11.28 | 20.60 | 32.07 | 7.01 | 42.47 |
| 220. | 99459. | 10.55 | 19.46 | 32.98 | 6.71 | 42.68 |
| 230. | 99998. | 9.90 | 18.49 | 33.93 | 6.41 | 42.83 |
| 240. | 100520. | 9.27 | 17.61 | 34.77 | 6.08 | 42.96 |
| 250. | 101029. | 8.64 | 16.67 | 35.41 | 5.74 | 43.01 |
| 260. | 101483. | 8.17 | 15.84 | 36.09 | 5.41 | 43.06 |
| 270. | 102296. | 7.88 | 15.00 | 36.60 | 5.09 | 42.94 |
| 280. | 102980. | 7.63 | [illegible] | 37.[illegible] | [illegible].79 | 42.85 |
| 290. | [illegible] | 7.37 | [illegible] | 37.7[illegible] | 4.[illegible] | 42.73 |
| 300. | [illegible] | 6.57 | 12.[illegible] | 38.30 | [illegible] | 42.55 |
| 310. | [illegible] | 6.[illegible]4 | 11.[illegible] | [illegible] | [illegible] | 42.44 |
| 320. | [illegible] | 6.17 | 12.29 | [illegible] | [illegible] | 42.24 |
| 330. | [illegible] | 5.[illegible] | [illegible]3 | [illegible] | [illegible] | 42.00 |
| 340. | [illegible] | 5.[illegible] | [illegible] | [illegible] | [illegible].24 | [illegible] |
| 350. | [illegible] | 5.[illegible] | [illegible]5 | [illegible] | [illegible].0[illegible] | 41.7[illegible] |
| 360. | [illegible] | 5.[illegible] | 9.[illegible] | [illegible] | 2.[illegible] | 41.6[illegible] |
| 370. | 107414. | 4.90 | 9.[illegible] | 38.34 | [illegible] | 41.5[illegible] |
| 380. | [illegible] | 4.[illegible]4 | 9.[illegible] | 37.64 | [illegible] | [illegible] |
| 390. | [illegible] | [illegible] | [illegible] | 37.88 | [illegible] | [illegible].27 |
| 400. | [illegible] | 4.47 | [illegible] | 37.[illegible] | [illegible] | [illegible].12 |

# STATION 1

## Q VS. AVAILABLE HABITAT AREA AS A PERCENTAGE OF THE GROSS AREA FOR RAINBOW TROUT

| Q | GROSS | FRY | JUVENILES | ADULT | SPAWNING | INCUBATION |
|---|---|---|---|---|---|---|
| 410. | 108216. | 4.33 | 8.02 | 37.44 | 2.50 | 40.96 |
| 420. | 108405. | 4.19 | 7.79 | 37.24 | 2.45 | 40.77 |
| 430. | 108592. | 4.07 | 7.61 | 37.02 | 2.41 | 40.54 |
| 440. | 108777. | 4.01 | 7.42 | 36.60 | 2.39 | 40.29 |
| 450. | 108960. | 3.95 | 7.24 | 36.20 | 2.37 | 40.02 |
| 460. | 109140. | 3.91 | 7.09 | 35.80 | 2.34 | 39.73 |
| 470. | 109319. | 3.88 | 6.98 | 35.44 | 2.32 | 39.41 |
| 480. | 109495. | 3.82 | 6.87 | 35.12 | 2.31 | 39.06 |
| 490. | 109670. | 3.69 | 6.74 | 34.74 | 2.28 | 38.67 |
| 500. | 109843. | 3.58 | 6.66 | 34.35 | 2.26 | 38.27 |
| 510. | 110014. | 3.47 | 6.58 | 33.95 | 2.23 | 37.87 |
| 520. | 110183. | 3.38 | 6.49 | 33.56 | 2.19 | 37.48 |
| 530. | 110350. | 3.29 | 6.40 | 33.17 | 2.14 | 37.09 |
| 540. | 110516. | 3.22 | 6.32 | 32.80 | 2.10 | 36.69 |
| 550. | 110680. | 3.18 | 6.26 | 32.41 | 2.06 | 36.27 |
| 560. | 110789. | 3.14 | 6.21 | 32.05 | 2.01 | 35.86 |
| 570. | 110874. | 3.12 | 6.16 | 31.68 | 1.98 | 35.45 |
| 580. | 110958. | 3.09 | 6.11 | 31.29 | 1.94 | 35.03 |
| 590. | 111041. | 3.06 | 6.06 | 30.91 | 1.90 | 34.61 |
| 600. | 111123. | 3.01 | 5.99 | 30.56 | 1.86 | 34.17 |
| 610. | 111204. | 2.93 | 5.89 | 30.21 | 1.83 | 33.73 |
| 620. | 111285. | 2.86 | 5.82 | 29.86 | 1.80 | 33.29 |
| 630. | 111365. | 2.79 | 5.75 | 29.51 | 1.76 | 32.87 |
| 640. | 111444. | 2.73 | 5.68 | 29.21 | 1.74 | 32.45 |
| 650. | 111522. | 2.66 | 5.62 | 28.91 | 1.71 | 32.05 |
| 660. | 111600. | 2.60 | 5.56 | 28.67 | 1.69 | 31.64 |
| 670. | [illegible] | [illegible] | 5.52 | [illegible] | 1.67 | 31.28 |
| 680. | [illegible] | [illegible] | [illegible] | [illegible] | 1.64 | 30.93 |
| 690. | 111830. | [illegible] | [illegible] | [illegible] | 1.61 | 30.59 |
| 700. | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 30.25 |
| 710. | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 720. | [illegible] | [illegible] | [illegible] | [illegible] | 1.54 | 29.39 |
| 730. | [illegible] | [illegible] | [illegible] | [illegible] | 1.51 | [illegible] |
| 740. | [illegible] | [illegible] | [illegible] | [illegible] | 1.49 | 28.97 |
| 750. | [illegible] | [illegible] | [illegible] | [illegible] | 1.47 | 28.86 |
| 760. | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 28.36 |
| 770. | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 780. | [illegible] | [illegible] | [illegible] | 26.05 | 1.41 | [illegible] |
| 790. | [illegible] | [illegible] | 5.00 | 25.85 | 1.38 | 27.51 |
| 800. | 112604. | 1.93 | 4.94 | 25.67 | 1.36 | 27.24 |

# Station 1

Q VS. AVAILABLE HABITAT AREA AS A PERCENTAGE OF THE GROSS AREA FOR MOUNTAIN WHITEFISH

| Q | GROSS | FRY | JUVENILE | ADULT | SPAWNING |
|---|---|---|---|---|---|
| 20. | 57102. | 7.50 | 11.80 | 11.57 | 3.27 |
| 30. | 74310. | 5.47 | 9.63 | 9.38 | 3.80 |
| 40. | 80716. | 4.76 | 9.88 | 9.07 | 4.79 |
| 50. | 84254. | 4.38 | 11.09 | 9.15 | 6.58 |
| 60. | 86383. | 4.17 | 12.37 | 9.42 | 9.40 |
| 70. | 87916. | 4.10 | 14.64 | 9.24 | 11.28 |
| 80. | 89055. | 3.96 | 17.41 | 10.52 | 13.32 |
| 90. | 90038. | 3.91 | 21.39 | 10.92 | 15.76 |
| 100. | 90588. | 3.95 | 25.94 | 11.43 | 19.94 |
| 110. | 91103. | 4.07 | 30.11 | 11.93 | 24.22 |
| 120. | 91584. | 4.13 | 32.91 | 12.37 | 27.96 |
| 130. | 94177. | 4.06 | 34.60 | 12.52 | 29.39 |
| 140. | 94844. | 4.14 | 36.65 | 12.93 | 31.12 |
| 150. | 95331. | 4.25 | 38.06 | 13.38 | 32.92 |
| 160. | 95797. | 4.31 | 38.97 | 13.85 | 34.63 |
| 170. | 96244. | 4.35 | 39.39 | 14.35 | 36.01 |
| 180. | 97458. | 4.36 | 39.01 | 14.78 | 36.67 |
| 190. | 97826. | 4.42 | 38.69 | 15.39 | 37.41 |
| 200. | 98331. | 4.49 | 37.92 | 16.01 | 37.63 |
| 210. | 98904. | 4.53 | 36.84 | 16.66 | 37.99 |
| 220. | 99459. | 4.59 | 35.82 | 17.37 | 37.81 |
| 230. | 99998. | 4.63 | 34.79 | 18.12 | 37.45 |
| 240. | 100520. | 4.66 | 33.78 | 18.87 | 36.96 |
| 250. | 101029. | 4.68 | 32.60 | 19.63 | 36.34 |
| 260. | 101483. | 4.69 | 31.94 | 20.40 | 35.58 |
| 270. | 102296. | 4.68 | 30.97 | 21.07 | 34.53 |
| [illegible] | [illegible] | 4.67 | [illegible] | 21.76 | [illegible] |
| 290. | [illegible] | 4.65 | [illegible] | 22.47 | [illegible] |
| 300. | [illegible] | 4.65 | [illegible] | [illegible] | [illegible] |
| 310. | [illegible] | 4.64 | [illegible] | [illegible] | [illegible] |
| 320. | 105621. | 4.65 | [illegible] | [illegible] | [illegible] |
| 330. | [illegible] | 4.61 | [illegible] | [illegible] | [illegible] |
| 340. | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 350. | [illegible] | 4.72 | [illegible] | [illegible] | [illegible] |
| 360. | [illegible] | 4.76 | [illegible] | [illegible] | [illegible] |
| 370. | [illegible] | 4.79 | [illegible] | [illegible] | [illegible] |
| 380. | [illegible] | [illegible] | [illegible] | 27.61 | [illegible] |
| 390. | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 400. | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

# STATION 1

## Q VS. AVAILABLE HABITAT AREA AS A PERCENTAGE OF THE GROSS AREA FOR MOUNTAIN WHITEFISH

| Q | GROSS | FRY | JUVENILE | ADULT | SPAWNING |
|---|---|---|---|---|---|
| 410. | 108216. | 4.97 | 26.33 | 28.83 | 24.46 |
| 420. | 108405. | 5.04 | 26.13 | 29.10 | 23.87 |
| 430. | 108592. | 5.09 | 25.92 | 29.29 | 23.37 |
| 440. | 108777. | 5.13 | 25.69 | 29.39 | 22.92 |
| 450. | 108960. | 5.17 | 25.48 | 29.22 | 22.48 |
| 460. | 109140. | 5.22 | 25.25 | 29.23 | 22.07 |
| 470. | 109319. | 5.23 | 25.01 | 29.33 | 21.71 |
| 480. | 109495. | 5.25 | 24.78 | 29.38 | 21.39 |
| 490. | 109670. | 5.26 | 24.52 | 29.44 | 21.12 |
| 500. | 109843. | 5.26 | 24.22 | 29.54 | 20.90 |
| 510. | 110014. | 5.27 | 23.93 | 29.63 | 20.71 |
| 520. | 110183. | 5.28 | 23.63 | 29.68 | 20.53 |
| 530. | 110350. | 5.30 | 23.35 | 29.71 | 20.35 |
| 540. | 110516. | 5.31 | 23.11 | 29.80 | 20.16 |
| 550. | 110680. | 5.30 | 22.86 | 29.87 | 20.00 |
| 560. | 110789. | 5.30 | 22.62 | 29.97 | 19.88 |
| 570. | 110874. | 5.31 | 22.41 | 30.03 | 19.76 |
| 580. | 110958. | 5.30 | 22.20 | 30.12 | 19.72 |
| 590. | 111041. | 5.31 | 21.98 | 30.17 | 19.66 |
| 600. | 111123. | 5.30 | 21.77 | 30.13 | 19.57 |
| 610. | 111204. | 5.29 | 21.59 | 30.08 | 19.47 |
| 620. | 111285. | 5.29 | 21.40 | 30.03 | 19.36 |
| 630. | 111365. | 5.29 | 21.26 | 30.02 | 19.26 |
| 640. | 111444. | 5.28 | 21.11 | 30.01 | 19.18 |
| 650. | 111522. | 5.27 | 20.94 | 30.02 | 19.11 |
| 660. | 111600. | 5.25 | 20.80 | 30.02 | 19.02 |
| 670. | [illegible] | [illegible] | 20.74 | 30.01 | [illegible].95 |
| 680. | [illegible] | [illegible] | [illegible] | [illegible] | [illegible].88 |
| 690. | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 700. | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 710. | [illegible]79. | [illegible] | [illegible].44 | [illegible] | [illegible].77 |
| 720. | [illegible] | [illegible] | [illegible] | [illegible].79 | [illegible].80 |
| 730. | [illegible] | [illegible].27 | [illegible] | [illegible] | [illegible].84 |
| 740. | [illegible]00. | [illegible] | [illegible] | [illegible] | [illegible].80 |
| 750. | [illegible] | [illegible] | [illegible] | [illegible] | [illegible].74 |
| 760. | [illegible] | [illegible] | [illegible] | [illegible].37 | [illegible] |
| 770. | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 780. | [illegible] | [illegible] | [illegible] | [illegible] | [illegible].55 |
| 790. | [illegible] | [illegible] | [illegible] | 29.06 | [illegible] |
| 800. | 112604. | 5.17 | 19.07 | 28.92 | 18.40 |

# Station 2

Q VS. AVAILABLE HABITAT AREA AS A PERCENTAGE OF THE GROSS AREA FOR RAINBOW TROUT

| Q | GROSS | FRY | JUVENILES | ADULT | SPAWNING | INCUBATION |
|---|---|---|---|---|---|---|
| ~~30.~~ | ~~53362.~~ | ~~4.92~~ | ~~5.27~~ | ~~3.49~~ | ~~5.16~~ | ~~8.56~~ |
| 40. | 88228. | 11.12 | 8.13 | 4.19 | 6.13 | 10.04 |
| ~~50.~~ | ~~91761.~~ | ~~10.72~~ | ~~11.51~~ | ~~4.87~~ | ~~6.25~~ | ~~11.63~~ |
| 60. | 93834. | 10.66 | 13.02 | 5.97 | 6.55 | 13.25 |
| ~~70.~~ | ~~94930.~~ | ~~10.71~~ | ~~13.27~~ | ~~7.28~~ | ~~7.12~~ | ~~15.01~~ |
| 80. | 96265. | 11.47 | 13.86 | 8.77 | 7.59 | 16.93 |
| ~~90.~~ | ~~97274.~~ | ~~12.64~~ | ~~14.86~~ | ~~10.74~~ | ~~7.77~~ | ~~18.52~~ |
| 100. | 97976. | 13.42 | 15.67 | 12.87 | 7.88 | 20.11 |
| ~~110.~~ | ~~98668.~~ | ~~13.00~~ | ~~16.20~~ | ~~14.85~~ | ~~7.92~~ | ~~21.68~~ |
| 120. | 99322. | 12.77 | 16.6[illegible] | 16.79 | 7.88 | 23.03 |
| 130. | 99930. | 12.72 | 17.3[illegible] | 18.53 | 7.96 | 24.20 |
| 140. | 100[illegible] | 13.[illegible]3 | 17.86 | 20.2[illegible] | 7.99 | [illegible].22 |
| 150. | 10[illegible] | 13.[illegible]7 | [illegible].23 | 21.76 | 7.9[illegible] | 26.[illegible]9 |
| 160. | 10[illegible] | [illegible].97 | [illegible].27 | 23.2[illegible] | 7.[illegible] | 27.11 |
| 170. | [illegible] | 12.[illegible]7 | [illegible].30 | 24.9[illegible] | 7.69 | [illegible].93 |
| 180. | [illegible] | 12.24 | 18.49 | 26.0[illegible] | 7.[illegible] | 28.75 |
| 190. | [illegible]20. | [illegible]1.81 | 18.52 | 28.13 | 7.[illegible] | 29.[illegible]3 |
| 200. | 103[illegible] | 11.[illegible] | 18.56 | 29.[illegible] | 7.[illegible] | 30.24 |
| 210. | 103[illegible] | [illegible].62 | [illegible] | [illegible].02 | 7.[illegible] | [illegible] |
| 220. | 104[illegible] | [illegible].07 | [illegible] | 32.[illegible] | 6.74 | [illegible].[illegible]4 |
| 230. | [illegible] | 9.[illegible] | [illegible] | 32.[illegible] | 6.46 | 3[illegible].71 |
| 240. | [illegible] | 9.[illegible]4 | 17.04 | [illegible] | 6.20 | [illegible].00 |
| 250. | [illegible] | [illegible] | [illegible].49 | [illegible] | [illegible] | [illegible] |
| 260. | [illegible] | [illegible] | [illegible].76 | [illegible].40 | 5.[illegible] | [illegible] |
| 270. | 106[illegible] | 7.[illegible] | [illegible]6 | 31.44 | 5.[illegible] | [illegible] |
| 280. | 10[illegible] | 7.[illegible] | 14.64 | 30.44 | [illegible] | [illegible].71 |
| 290. | [illegible] | 7.[illegible] | [illegible].07 | [illegible] | [illegible] | [illegible].65 |
| 300. | [illegible] | 6.99 | [illegible] | 29.[illegible] | [illegible] | [illegible].62 |
| 310. | [illegible] | 6.72 | [illegible] | 2[illegible] | [illegible] | [illegible].53 |
| 320. | [illegible] | 6.[illegible] | 12.70 | [illegible] | [illegible].39 | 32.39 |
| 330. | [illegible] | 6.[illegible] | 12.17 | [illegible] | [illegible].2[illegible] | [illegible].26 |
| 340. | [illegible] | 6.24 | [illegible] | [illegible].49 | [illegible] | [illegible] |
| 350. | [illegible] | 6.2[illegible] | [illegible] | [illegible] | [illegible] | [illegible].47 |
| 360. | [illegible] | 6.[illegible]3 | [illegible] | [illegible].00 | [illegible] | [illegible] |

# STATION 2

## Q VS. AVAILABLE HABITAT AREA AS A PERCENTAGE OF THE GROSS AREA FOR RAINBOW TROUT

| Q | GROSS | FRY | JUVENILES | ADULT | SPAWNING | INCUBATION |
|---|---|---|---|---|---|---|
| 370. | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 380. | [illegible] | [illegible] | [illegible] | [illegible] | 4.42 | 29.28 |
| 390. | 11670[illegible]. | [illegible] | 9.11 | [illegible] | 4.31 | [illegible].30 |
| 400. | [illegible] | 4.47 | [illegible] | [illegible] | [illegible] | [illegible].30 |
| 410. | [illegible]0804. | 4.19 | 7.90 | 22.65 | [illegible] | [illegible]6.66 |
| 420. | [illegible]854. | 3.7[illegible] | 7.34 | 21.2[illegible] | 4.[illegible] | [illegible]6.33 |
| 430. | [illegible]0904. | [illegible] | 6.[illegible] | [illegible].28 | 4.[illegible] | 26.[illegible]3 |
| 440. | [illegible] | [illegible] | 6.90 | [illegible].66 | [illegible] | 25.[illegible] |
| 450. | [illegible] | [illegible] | 6.88 | [illegible] | 3.77 | [illegible] |
| 460. | [illegible] | [illegible] | 6.[illegible] | 19.[illegible] | [illegible].64 | [illegible].73 |
| 470. | [illegible] | 2.93 | 6.7[illegible] | 19.[illegible]7 | 3.[illegible] | [illegible].[illegible]3 |
| 480. | 119[illegible]. | 2.07 | 6.[illegible]8 | 19.[illegible] | [illegible] | [illegible] |

# Station 3

Q VS. AVAILABLE HABITAT AREA AS A PERCENTAGE
OF THE GROSS AREA FOR CUTTHROAT TROUT

| Q | GROSS | FRY | JUVENILE | ADULTS | SPAWNING | INCUBATION |
|---|---|---|---|---|---|---|
| 10. | 50323. | 3.72 | 1.68 | 2.76 | .66 | 2.56 |
| 20. | 53517. | 17.55 | 9.74 | 12.14 | .46 | 7.59 |
| 30. | 55[illegible] | 26.24 | 19.20 | 19.42 | 1.65 | [illegible] |
| 40. | 59503. | 26.64 | 26.03 | 22.91 | 2.83 | 17.60 |
| 50. | 62070. | 24.77 | 28.87 | 26.57 | 3.60 | 22.04 |
| 60. | 65136. | 22.57 | 29.87 | 27.27 | 4.15 | 27.72 |
| 70. | 67733. | 20.33 | 30.41 | 29.80 | 4.63 | 32.01 |
| 80. | 68950. | 18.33 | 30.13 | 31.74 | 5.11 | 36.21 |
| 90. | 69191. | 16.20 | 31.07 | 32.50 | 5.44 | 40.06 |
| 100. | 70723. | 14.36 | 30.89 | 33.11 | 5.87 | 43.55 |
| 110. | 71449. | 12.77 | 30.24 | 33.13 | 6.20 | 46.42 |
| 120. | 72128. | 11.35 | 29.28 | 33.03 | 6.21 | 49.95 |
| 130. | 72617. | 10.16 | 28.26 | 33.19 | 6.47 | 50.99 |
| 140. | 73048. | 9.15 | 27.25 | 33.20 | 6.42 | 52.87 |
| 150. | 73405. | 8.25 | 26.20 | 33.73 | 6.21 | 54.43 |
| 160. | 73745. | 7.45 | 24.98 | 34.38 | 6.11 | 55.70 |
| 170. | 74070. | 6.74 | 23.70 | 34.50 | 5.81 | 56.49 |
| 180. | 74381. | 6.13 | 22.36 | 33.96 | 5.42 | 57.46 |
| 190. | 74[illegible] | 5.57 | 20.73 | 32.06 | 5.01 | 57.98 |
| 200. | 74967. | 5.10 | 18.86 | 31.75 | 4.74 | 58.30 |
| 210. | 75243. | 4.68 | 16.90 | 30.33 | 4.61 | 58.23 |
| 220. | 75[illegible] | 4.31 | 14.83 | 29.00 | 4.53 | 59.16 |
| 230. | 75[illegible] | 3.98 | 12.81 | 27.30 | 4.46 | 57.93 |
| 240. | 76017. | 3.68 | 11.13 | 25.30 | 4.37 | 57.20 |
| 250. | 76260. | [illegible] | 9.75 | 23.02 | 4.23 | 56.17 |
| 260. | 764[illegible]5. | [illegible].22 | 8.56 | 20.98 | 4.01 | 56.06 |
| 270. | 76[illegible]24. | 3.67 | 7.62 | 18.92 | 3.81 | 55.26 |
| 280. | 769[illegible] | [illegible] | 6.97 | 16.[illegible]6 | 3.69 | 54.36 |
| 290. | 7716[illegible] | [illegible] | 6.43 | 14.72 | 3.61 | 53.42 |
| 300. | 77374. | [illegible] | 5.86 | 12.87 | 3.53 | 52.36 |
| 310. | 77580. | 2.[illegible] | 5.39 | 11.19 | 3.48 | 51.[illegible]0 |
| 320. | [illegible]81. | [illegible].68 | 5.06 | 10.66 | 3.43 | 50.02 |
| 330. | [illegible]16. | [illegible].51 | 4.73 | 8.94 | 3.36 | 48.88 |
| [illegible] | [illegible]10. | 2.51 | 4.45 | 7.84 | 3.29 | 47.72 |
| 350. | 78359. | 2.[illegible] | 4.27 | 6.99 | 3.24 | 46.54 |

Appendix D

Annotations to habitat type classification system for North Fork Snoqualmie basin proposed reservoir area.

| | |
|---|---|
| M/S - Marsh/Swamp | Area of poorly drained soils with standing water during most of the year. Vegetation is dominated by succulents, such as cat-tail (Typha latifolia), sedges (Carex spp.), skunk cabbage (Lysichitum americanum), and false hellebore (Veratrum sp.), and/or woody plants, such as willow (Salix spp.), and western red cedar (Thuja plicata). |
| B - Bog | Area of poorly-drained, acid soils, with standing water during part of the year. Vegetation is dominated by non-woody vegetation such as Sphagnum spp., bogbean (Menyanthes trifoliata), sundew (Drosera rotundifolia), and bog cranberry (Vaccinium oxycoccos), and woody vegetation such as Labrador tea (Ledum groenlandicum) and bog laurel (Kalmia occidentalis). |
| P - Pond | Enclosed body of water, which is less than 2 ha (5 acres) in area and less than 6 m (20 ft) deep. Formed as an oxbow, or as a result of beavers. |
| R/S - River/Stream | Area covered by flowing water during part of year. Includes sand and gravel bars and moderately-sloped to level banks. |
| FE/M - Early Successional Forest/Marsh | Raised areas of dry soil in early stages of reforestation, interspersed with wet areas of marsh/swamp vegetation (see above). Dry areas are dominated by low woody vegetation such as huckleberry (Vaccinium spp.) and salmonberry (Rubus spectabilis), and young conifers such as Douglas fir (Pseudotsuga menziesii) and western hemlock (Tsuga heterophylla). These young trees may be seedlings, or may overtop surrounding shrubs, but always have open canopies. |
| FE - Early Successional Forest | Area in early stages of reforestation, dominated by herbaceous vegetation such as fireweed (Epilobium angustifolium) and foxglove (Digitalis purpurea), shrubs such as huckleberry and salmonberry, and young trees such as red alder (Alnus rubra) and/or Douglas fir and western hemlock. Canopy always open. |
| FCP - Pole Stage Coniferous Forest | Forest stand dominated by sapling coniferous species, usually Douglas fir or western hemlock, with a closed canopy excluding light and undergrowth. |

| | |
|---|---|
| FCM/O - Mature/Old Growth Coniferous Forest | Forest stand dominated by mature or over-mature conifers such as Douglas fir, western hemlock, and western red cedar, but also Pacific silver fir (*Abies amabilis*) at higher elevations. Usually characterized by uneven-aged, multi-layered canopy, with scattered broadleaf trees and snags, and interspersed with clearings dominated by vine maple (*Acer circinatum*), salmonberry, and devil's club (*Oplopanax horridum*). |
| FB - Broadleaf Forest | Forest stand dominated by broadleaf species, usually red alder. Most stands have closed canopies 4.5-7.5 m (15-25 ft) tall and understories of shrubs, such as salmonberry and devil's club. |
| FM - Mixed Forest | Forest stand dominated by a mixture of coniferous and broadleaf trees, usually red alder, and western hemlock or Douglas fir. Most stands are of intermediate age, with pole stage conifers and broadleaf trees 4.5-7.5 m (15-25 ft) tall. |
| S - Sand Slide | Steep area of sand, usually along a river, stream or road, which is eroding rapidly enough to prevent establishment of vegetation. |
| L - Logging Road | Main road used to transport logs. Also includes borrow pits. |

Appendix E

Description and use of antenna system employed in deer radiotelemetry study, North Fork Snoqualmie basin, 1980.

The antenna system used to monitor radiocollared deer in this project mounts atop the cab of a truck and rotates 360° horizontally (Fig. E-1). Figure E-2 shows materials, dimensions, and assembly.

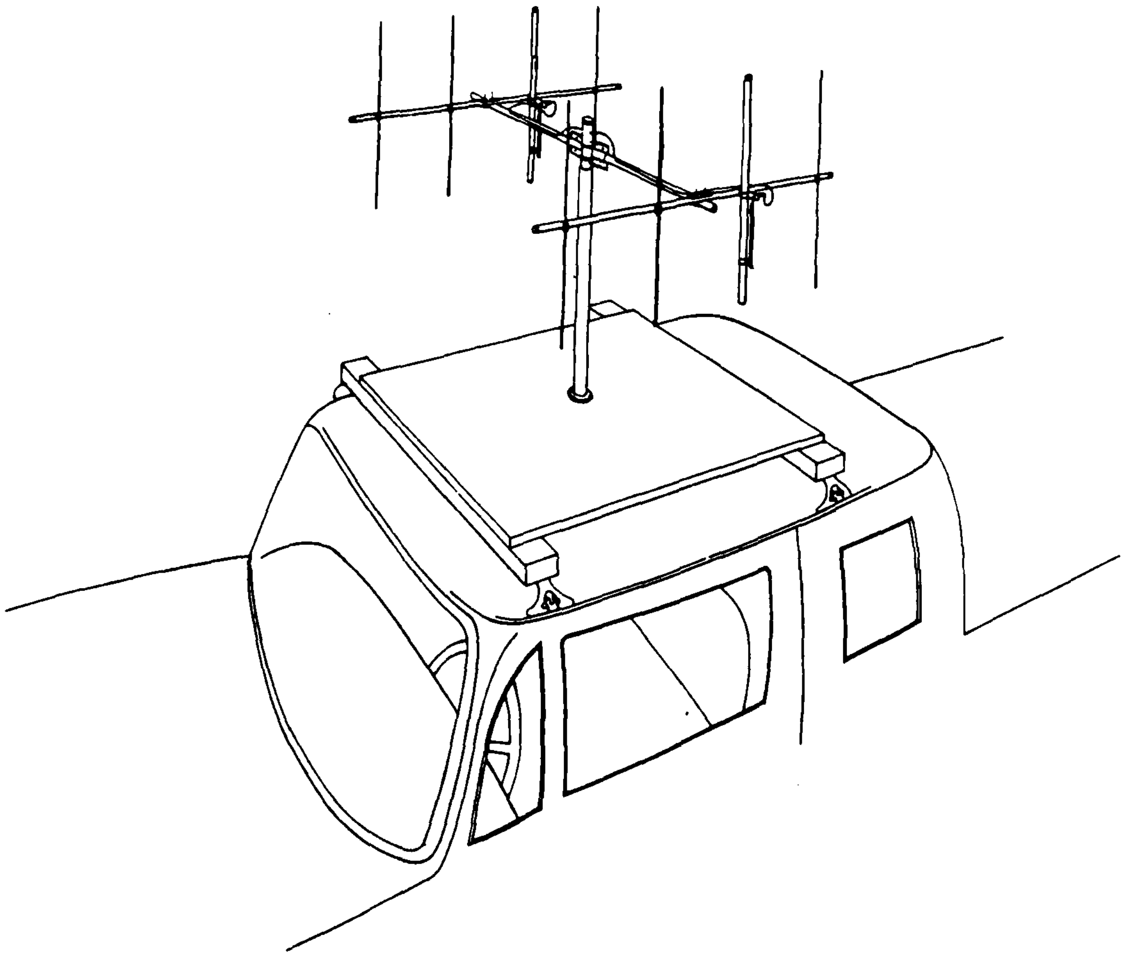
The system features two 4-element directional yagi antennas (AVM Instrument Co.), fastened parallel in a vertical plane, at either end of a horizontal tubular aluminum alloy boom. The boom is clamped to a tubular mast of the same material. The mast passes through the roof of the cab, and down through a hole in the center of the front seat to the floor. It can thus be turned from inside the cab, rotating the antennas.

The mast is stabilized by a piece of steel pipe, which acts as a sleeve. This sleeve extends from just below the boom, through a wooden stabilizing platform mounted on the roof of the cab, and into the cab just a few inches. The lower third of the sleeve is threaded, and fastens to the top and bottom of the platform and cab with large-diameter nuts and washers. Rubber doughnuts (made from inner tubes), and stoppers seal the cab and sleeve. A clamp on the lower end of the sleeve is used to secure the antenna when taking compass bearings on a deer's radio signal.

Transmitting cables pass from the antennas, along the outside of the boom, through the wall of the mast (sealed with rubber washers), down through the mast and into the cab. A vertical slot, cut from the base of the mast to the height of the seat, allows the ends of the cables to project at seat height within easy reach. There, they connect to a modified right-left switchbox (AVM Instrument Co.), which in turn connects to a 12-channel receiver (AVM Instrument Co., Model LA 12). Once assembled, the antenna-cable-mast complex is easily removed or installed whole, by simply standing atop the cab platform and lifting it out, or dropping it in. Platform and sleeve usually remain atop the truck, although they can be removed in a few minutes, if desired.

The operating mode usually recommended for such an antenna setup is the null-peak system. In this system, signals from both antennas are transmitted simultaneously to a null-peak switchbox, and then to a receiver. The null-peak switch shifts the phases of the signals from the two antennas by half a wavelength. This phase shift determines whether the combined signal will be a peak (maximum signal), or a null (a cancelled signal or blank space between two lesser peaks), when the antenna is pointed directly at the transmitter. The maximum signal during peak mode is quite broad, and is used mainly to find the general direction of the signal source. The blank signal during null mode is much narrower (more precise), and is used to obtain a more accurate bearing.

Figure E-1. Truck-mounted antenna system.



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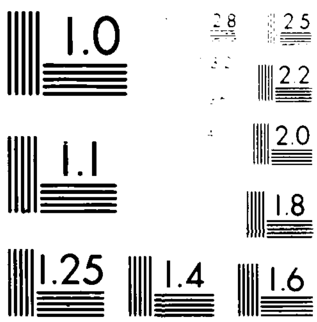
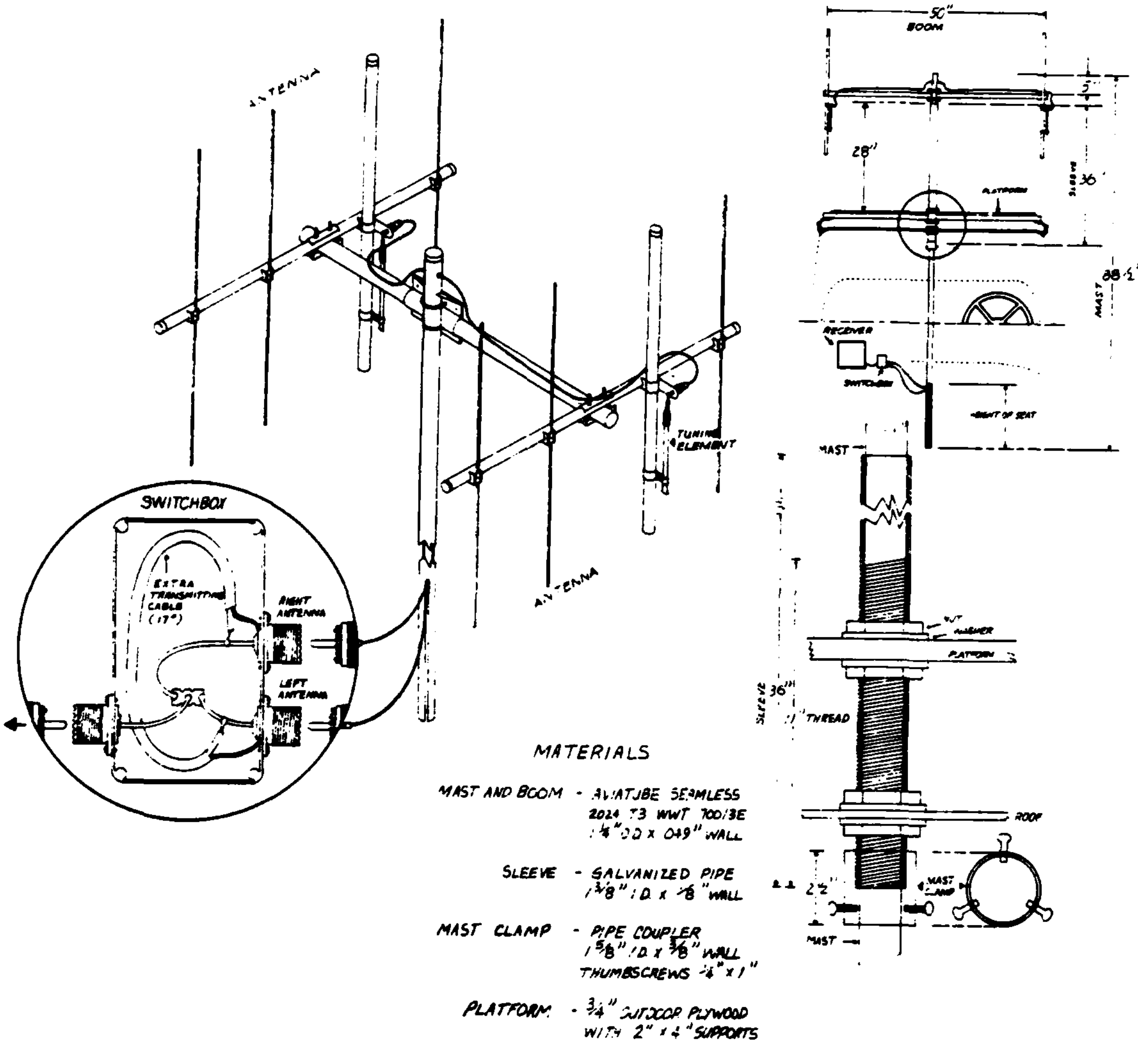



MICROCOPY RESOLUTION TEST CHART

Figure E-2. Components of antenna system.



The null-peak system works quite well in relatively flat, open country. However, according to Dr. Donald Reynolds (pers. commun., Dept. of Electrical Engineering, University of Washington, Seattle, Wash.), it is relatively unsatisfactory in the type of mountainous terrain found in our project area. This is because the narrow, blank signal used to accurately locate the direction of the transmitter, is often filled by signal reflections off mountains, rock faces, and other large objects. Thus, the broad, peak signal must often be used by itself to locate the signal source, resulting in an error of several degrees.

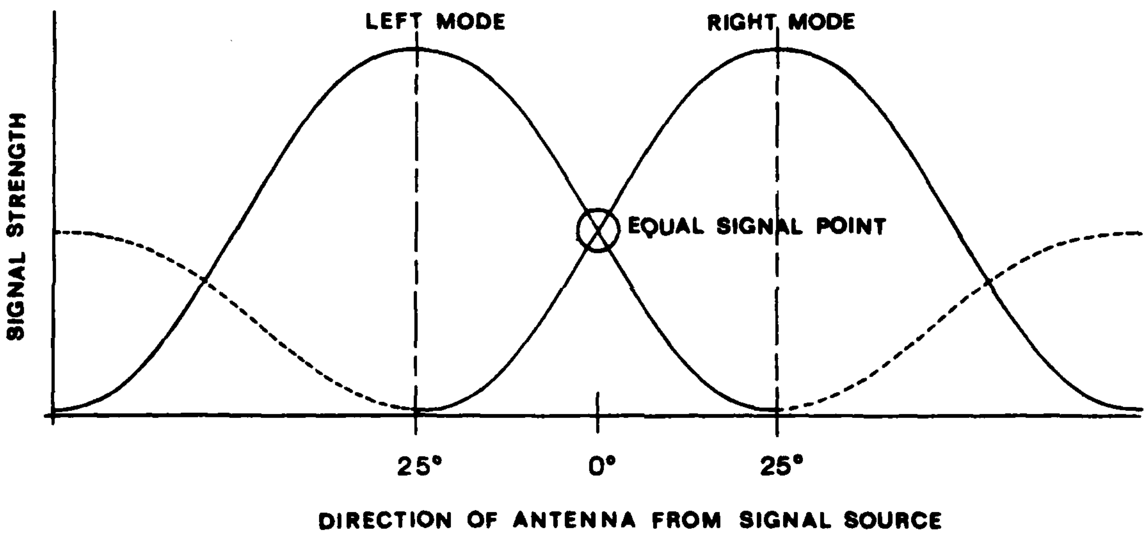
Instead of the null-peak system, Dr. Reynolds suggested we use a system developed during World War II for pinpointing enemy aircraft on radar. The method is known as lobe-switching, and required only minor modifications to our equipment. First, we had to mount both antennas so their tuning elements were pointed in the same direction (Fig. E-2), rather than opposite directions as in the null-peak system. Then we soldered a short length of transmitting cable, connecting the two antenna lead wires inside the right-left switchbox, as shown in Fig. E-2.

These two changes cause both antenna signals to be received simultaneously but slightly out of phase, when the antenna is pointed directly at the signal source. Position of the right-left switch determines which antenna signal must traverse the extra length of wire in the switchbox, and hence which antenna signal lags the other. Only by rotating the antenna to the left of the signal source (when switched to left mode), or right of the signal source (when switched to right mode), are the antenna signals brought into phase, and the maximum combined signal received (Fig. E-3).

These signal peaks are relatively broad, and by themselves are useful only for locating the general direction of the signal. However, Fig. E-3 shows that when we have a maximum signal in the left mode, the signal obtained by switching to the right mode is very weak. The reverse is also true. As we rotate the antenna <u>toward</u> the mode with the weaker signal, <u>it</u> gets stronger, while the other mode's signal weakens. We continue rotating the antenna and switching modes, until the signal strength is the same with the switch in either position. <u>The antenna is now pointing directly at the transmitter</u>.

The lobe-switching method is extremely precise, and with antennas properly tuned, accurate to within 1 or 2 degrees of the true signal direction. This accuracy results from using the <u>sides</u> of the signal pattern, where a small change in antenna direction results in a large change in signal strength (Fig. E-3). In contrast, systems which use the broad <u>peak</u> of the signal pattern, where a larger change in antenna direction is needed to change signal strength, are accurate to within only about 10 or 15 degrees.

Figure E-3. Signal Pattern.



Under most conditons, we found this antenna system very satisfactory. Our only problems were: 1) occasionally distinguishing a true signal from reflected signals in narrow, rocky drainages with large trees; 2) monitoring a deer which was moving; and 3) periodic interference from other radio sources. These problems were usually overcome with patience in locating animals.

In radiolocating deer, we attempted to minimize sources of error caused by signals bending or bouncing, and deer moving. Therefore, whenever possible we took compass bearings on an animal from four separate locations. These locations were usually standard road sites, close to, and with a direct view of a deer's known general locality. Bearings were taken by standing outside the truck, and reading the antenna's direction from a hand-held compass. We always stood at least 3 m (10 ft) away from the truck to avoid its magnetic influence.

Bearings of radiocollared deer were transferred to a WDNR Orthophoto Map (scale 1:24,000) of the project area. An animal's location was taken as the point or smallest triangle, formed by the intersection of three bearings.

The antenna system described here is reliable and extremely sturdy. We drove it assembled, over miles of logging roads and freeways without mishap. It is also cheap to build, once the antennas, receiver, and switchbox are purchased. With these three items already in our possession, we put together the entire system from materials costing less than 75 dollars.

## Appendix F

Calculations for estimated seasonal densities of common birds in five habitat types, North Fork Snoqualmie basin, 1979.

Spring Census--Early Successional Forest (FE)

| Species | Stations | Detection distance (r) | $\pi r^2$ | Hearing area(hectares) | Birds | Birds/ha |
|---|---|---|---|---|---|---|
| St. Jay | 10 | 200 | 125,600 | 125.60 | 4 | 0.03 |
| D.-e. Ju. | 10 | 70 | 15,386 | 15.39 | 8 | 0.52 |
| MacG. W. | 10 | 100 | 31,400 | 31.40 | 4 | 0.13(0.26)* |
| Am. Rob. | 10 | 200 | 125,600 | 125.60 | 9 | 0.07(0.14) |
| O.-c. W. | 10 | 150 | 70,650 | 70.65 | 5 | 0.07(0.14) |
| Song Sp. | 10 | 100 | 31,400 | 31.40 | 2 | 0.06(0.12) |
| Wils. W. | 10 | 170 | 90,746 | 90.75 | 1 | 0.01(0.02) |
| Ru. Hum. | 10 | 30 | 2,826 | 2.83 | 4 | 1.41 |
| W.-c. Sp. | 10 | 150 | 70,650 | 70.65 | 7 | 0.10(0.20) |
| Com. Yel. | 10 | 70 | 15,386 | 15.39 | +** | + |
| Wil. Fly. | 10 | 100 | 31,400 | 31.40 | 1 | 0.03(0.06) |
| Com. Crow | 10 | 170 | 90,746 | 90.75 | + | + |
| Com. Flick. | 10 | 200 | 125,600 | 125.60 | 2 | 0.02 |

*Numbers in parentheses are for both sexes, where only singing males were counted.

**A "+" means that bird was observed outside of detection distance.

Spring Census—Pole Stage Coniferous Forest (FCP)

| Species | Stations | Detection distance (r) | $\pi r^2$ | Hearing area(hectares) | Birds | Birds/ha |
|---|---|---|---|---|---|---|
| St. Jay | 28 | 100 | 31,400 | 87.92 | 8 | 0.09 |
| Town. W. | 28 | 50 | 7,850 | 21.98 | 10 | 0.45(0.90) |
| We. Fly. | 28 | 50 | 7,850 | 21.98 | 5 | 0.23(0.46) |
| O.-c. W. | 28 | 60 | 11,304 | 31.65 | 11 | 0.35(0.70) |
| Y.-r. W. | 28 | 30 | 2,826 | 7.91 | 3 | 0.38(0.76) |
| Pil. Wood. | 28 | 150 | 70,650 | 197.82 | 2 | 0.01 |
| G.-c. K. | 28 | 30 | 2,826 | 7.91 | 9 | 1.14 |
| Var. Th. | 28 | 100 | 31,400 | 87.92 | 14 | 0.16 |
| Win. Wr. | 28 | 50 | 7,850 | 21.98 | 8 | 0.36(0.72) |
| B.-t. Pig. | 28 | 50 | 7,850 | 21.98 | 8 | 0.36(0.72) |
| Wils. W. | 28 | 100 | 31,400 | 87.92 | 24 | 0.27(0.54) |
| Am. Rob. | 28 | 100 | 31,400 | 87.92 | 7 | 0.08 |
| D.-e. Ju. | 28 | 50 | 7,850 | 21.98 | 5 | 0.23 |
| Her. Th. | 28 | 60 | 11,304 | 31.65 | 4 | 0.13 |

Spring Census--Pole Stage Coniferous Forest (FCP) - continued.

| Species | Stations | Detection distance (r) | $\pi r^2$ | Hearing area(hectares) | Birds | Birds/ha |
|---|---|---|---|---|---|---|
| Ru. Hum. | 28 | 20 | 1,256 | 3.52 | 2 | 0.57 |
| C.-b.C. | 28 | 30 | 2,826 | 7.91 | 4 | 0.51 |
| Swa. Th. | 28 | 100 | 31,400 | 87.92 | 8 | 0.09 |
| B.-c. C. | 28 | 30 | 2,826 | 7.91 | + | + |
| Com. Crow | 28 | 100 | 31,400 | 87.92 | + | + |
| MacG. W. | 28 | 70 | 15,386 | 43.08 | 2 | 0.05(0.10) |
| Hut. Vir. | 28 | 50 | 7,850 | 21.98 | 2 | 0.09(0.18) |

Spring Census--Mixed Forest (FM)

| Species | Stations | Detection distance (r) | $\pi r^2$ | Hearing area(hectares) | Birds | Birds/ha |
|---|---|---|---|---|---|---|
| Win. Wr. | 28 | 50 | 7,850 | 21.98 | 17 | 0.77 |
| Wils. W. | 28 | 100 | 31,400 | 87.92 | 13 | 0.15(0.30) |
| Am. Rob. | 28 | 100 | 31,400 | 87.92 | 11 | 0.13 |
| O.-c. W. | 28 | 60 | 11,304 | 31,65 | 9 | 0.28(0.56) |
| We. Fly. | 28 | 50 | 7,850 | 21.98 | 13 | 0.59 |
| St. Jay | 28 | 100 | 31,400 | 87.92 | 5 | 0.06 |
| Var. Th. | 28 | 100 | 31,400 | 87.92 | 7 | 0.08 |
| G.-c. K. | 28 | 30 | 2,826 | 7.91 | 9 | 1.14 |
| Town. W. | 28 | 50 | 7,850 | 21.98 | 14 | 0.64(1.28) |
| Song Sp. | 28 | 100 | 31,400 | 87.92 | 10 | 0.11(0.22) |
| Y.-r. W. | 28 | 30 | 2,826 | 7.91 | 7 | 0.88(1.76) |
| Ru. Hum. | 28 | 20 | 1,256 | 3.52 | 2 | 0.57 |
| MacG. W. | 28 | 70 | 15,386 | 43.08 | 1 | 0.02(0.04) |
| D.-e. Ju. | 28 | 50 | 7,850 | 21.98 | 2 | 0.09 |

Spring Census--Mixed Forest (FM) - continued.

| Species | Stations | Detection distance (r) | $\pi r^2$ | Hearing area(hectares) | Birds | Birds/ha |
|---|---|---|---|---|---|---|
| C.-b. C. | 28 | 30 | 2,826 | 7.91 | 6 | 0.76 |
| Pil. Wood. | 28 | 150 | 70,650 | 197.82 | 1 | 0.01 |
| Com. Crow | 28 | 100 | 31,400 | 87.92 | 1 | 0.01 |
| Com. Yel. | 28 | 40 | 5,024 | 14.07 | 1 | 0.07 |
| War. Vir. | 28 | 100 | 31,400 | 87.92 | 1 | 0.01(0.02) |
| Hut. Vir. | 28 | 50 | 7,850 | 21.98 | 5 | 0.23(0.46) |

Spring Census--Old Growth Coniferous Forest (FCM/O)

| Species | Stations | Detection distance (r) | $\pi r^2$ | Hearing area(hectares) | Birds | Birds/ha |
|---|---|---|---|---|---|---|
| We. Fly. | 16 | 50 | 7,850 | 12.56 | 14 | 1.11 |
| Win. Wr. | 16 | 50 | 7,850 | 12.56 | 10 | 0.80(1.60) |
| G.-c. K. | 16 | 30 | 2,826 | 4.52 | 6 | 1.33(2.66) |
| Wils. W. | 16 | 100 | 31,400 | 50.24 | 18 | 0.36(0.72) |
| C.-b. C. | 16 | 30 | 2,826 | 4.52 | 4 | 0.88 |
| Town. W. | 16 | 50 | 7,850 | 12.56 | 10 | 0.80(1.60) |
| St. Jay | 16 | 100 | 31,400 | 50.24 | 4 | 0.08 |
| Var. Th. | 16 | 100 | 31,400 | 50.24 | 3 | 0.06(0.12) |
| Song Sp. | 16 | 100 | 31,400 | 50.24 | 1 | 0.02(0.04) |
| Am. Rob. | 16 | 100 | 31,400 | 50.24 | 2 | 0.04 |
| Ru. Hum. | 16 | 20 | 1,256 | 2.01 | 4 | 1.99 |
| Ha. Wood. | 16 | 110 | 37,994 | 60.79 | 6 | 0.10 |
| Pil. Wood. | 16 | 150 | 70,650 | 113.04 | 1 | 0.01 |
| Swa. Th. | 16 | 100 | 31,400 | 50.24 | 1 | 0.02 |
| Com. Flick. | 16 | 130 | 53,066 | 84.91 | 2 | 0.02 |

Summer Census—Early Successional Forest (FE)

| Species | Stations | Detection distance (r) | $\pi r^2$ | Hearing area(hectares) | Birds | Birds/ha |
|---|---|---|---|---|---|---|
| MacG. W. | 10 | 100 | 31,400 | 31.40 | 12 | 0.38(0.76) |
| Am. Rob. | 10 | 200 | 125,600 | 125.60 | 7 | 0.06 |
| O.-c. W. | 10 | 150 | 70,650 | 70.65 | 10 | 0.14(0.28) |
| W.-c. Sp. | 10 | 150 | 70,650 | 70.65 | 12 | 0.17(0.34) |
| Wil. Fly. | 10 | 100 | 31,400 | 31.40 | 18 | 0.57(1.14) |
| Wils. W. | 10 | 170 | 90,746 | 90.75 | 2 | 0.02(0.04) |
| Swa. Th. | 10 | 200 | 125,600 | 125.60 | 14 | 0.11 |
| Var. Th. | 10 | 170 | 90,746 | 90.75 | 3 | 0.03(0.06) |
| Song Sp. | 10 | 100 | 31,400 | 31.40 | 9 | 0.29(0.58) |
| Win. Wr. | 10 | 90 | 25,434 | 25.43 | + | + |
| R.-s. Tow. | 10 | 100 | 31,400 | 31.40 | 8 | 0.25(0.50) |
| D.-e. Ju. | 10 | 70 | 15,386 | 15.39 | 1 | 0.06 |
| St. Jay | 10 | 200 | 125,600 | 125.60 | 1 | 0.01 |
| Com. Crow | 10 | 170 | 90,746 | 90.75 | + | + |
| Com. Flick. | 10 | 200 | 125,600 | 125.60 | + | + |

Summer Census--Pole Stage Coniferous Forest (FCP)

| Species | Stations | Detection distance (r) | $\pi r^2$ | Hearing area(hectares) | Birds | Birds/ha |
|---|---|---|---|---|---|---|
| Win. Wr. | 28 | 50 | 7,850 | 21.98 | 17 | 0.77 |
| B.-t. Pig. | 28 | 50 | 7,850 | 21.98 | 4 | 0.18 |
| Swa. Th. | 28 | 100 | 31,400 | 87.92 | 35 | 0.40 |
| D.-e. Ju. | 28 | 50 | 7,850 | 21.98 | 11 | 0.50 |
| G.-c. K. | 28 | 30 | 2,826 | 7.91 | 10 | 1.26 |
| Var. Th. | 28 | 100 | 31,400 | 87.92 | 35 | 0.40 |
| Am. Rob. | 28 | 100 | 31,400 | 87.92 | 7 | 0.08 |
| Wil. Fly. | 28 | 80 | 20,096 | 56.27 | 10 | 0.18(0.36) |
| Com. Crow | 28 | 100 | 31,400 | 87.92 | + | + |
| We. Fly. | 28 | 50 | 7,850 | 21.98 | 12 | 0.55 |
| O.-c. W. | 28 | 60 | 11,304 | 31.65 | 14 | 0.44(0.88) |
| Town. W. | 28 | 50 | 7,850 | 21.98 | 4 | 0.18(0.36) |
| Ru. Hum. | 28 | 20 | 1,256 | 3.52 | 1 | 0.28 |
| Her. Th. | 28 | 60 | 11,304 | 31.65 | 1 | 0.03 |
| St. Jay | 28 | 100 | 31,400 | 87.92 | 5 | 0.06 |

Summer Census—Pole Stage Coniferous Forest (FCP) - continued.

| Species | Stations | Detection distance (r) | $\pi r^2$ | Hearing area(hectares) | Birds | Birds/ha |
|---|---|---|---|---|---|---|
| Wils. W. | 28 | 100 | 31,400 | 87.92 | 10 | 0.11(0.22) |
| C.-b.C. | 28 | 30 | 2,826 | 7.91 | 3 | 0.38 |
| R.-s. Tow. | 28 | 60 | 11,304 | 31.65 | 1 | 0.03 |
| Song Sp. | 28 | 100 | 31,400 | 87.92 | 4 | 0.05(0.10) |
| Y.-r. W. | 28 | 30 | 2,826 | 7.91 | 1 | 0.13(0.26) |
| Ha. Wood. | 28 | 110 | 37,994 | 106.38 | 1 | 0.01 |
| MacG. W. | 28 | 70 | 15,386 | 43.08 | 2 | 0.05(0.10) |

Summer Census—Mixed Forest (FM)

| Species | Stations | Detection distance (r) | $\pi r^2$ | Hearing area(hectares) | Birds | Birds/ha |
|---|---|---|---|---|---|---|
| We. Fly. | 28 | 50 | 7,850 | 21.98 | 17 | 0.77 |
| Swa. Th. | 28 | 100 | 31,400 | 87.92 | 28 | 0.32 |
| Wils. W. | 28 | 100 | 31,400 | 87.92 | 19 | 0.22(0.44) |
| Var. Th. | 28 | 100 | 31,400 | 87.92 | 15 | 0.17 |
| Town. W. | 28 | 50 | 7,850 | 21.98 | 5 | 0.23(0.46) |
| Win. Wr. | 28 | 50 | 7,850 | 21.98 | 11 | 0.50 |
| D.-e. Ju. | 28 | 50 | 7,850 | 21.98 | 3 | 0.14 |
| Am. Rob. | 28 | 100 | 31,400 | 87.92 | 6 | 0.07 |
| St. Jay | 28 | 100 | 31,400 | 87.92 | 5 | 0.06 |
| Com. Crow | 28 | 100 | 31,400 | 87.92 | 4 | 0.05 |
| Com. Yel. | 28 | 40 | 5,024 | 14.07 | 1 | 0.07 |
| Song Sp. | 28 | 100 | 31,400 | 87.92 | 9 | 0.10(0.20) |
| G.-c. K. | 28 | 30 | 2,826 | 7.91 | 5 | 0.63 |
| Pil. Wood. | 28 | 150 | 70,650 | 197.82 | + | + |
| C.-b. C. | 28 | 30 | 2,826 | 7.91 | 5 | 0.63 |

Summer Census--Mixed Forest (FM) - continued.

| Species | Stations | Detection distance (r) | $\pi r^2$ | Hearing area(hectares) | Birds | Birds/ha |
|---|---|---|---|---|---|---|
| MacG. W. | 28 | 70 | 15,386 | 43.08 | 2 | 0.05(0.10) |
| B.-t. Pig. | 28 | 50 | 7,850 | 21.98 | 1 | 0.05 |
| Y.-r. W. | 28 | 30 | 2,826 | 7.91 | 1 | 0.13(0.26) |
| O.-c. W. | 28 | 60 | 11,304 | 31.65 | + | + |
| War. Vir. | 28 | 100 | 31,400 | 87.92 | 3 | 0.03(0.06) |
| Hut. Vir. | 28 | 50 | 7,850 | 21.98 | + | + |

Summer Census--Old Growth Coniferous Forest (FCM/O)

| Species | Stations | Detection distance (r) | $\pi r^2$ | Hearing area(hectares) | Birds | Birds/ha |
|---|---|---|---|---|---|---|
| Wils. W. | 17 | 100 | 31,400 | 53.38 | 14 | 0.26(0.52) |
| Swa. Th. | 17 | 100 | 31,400 | 53.38 | 18 | 0.34(0.68) |
| We. Fly. | 17 | 50 | 7,850 | 13.35 | 12 | 0.90(1.80) |
| G.-c. K. | 17 | 30 | 2,826 | 4.80 | 8 | 1.67(3.34) |
| Win. Wr. | 17 | 50 | 7,850 | 13.35 | 8 | 0.60(1.20) |
| Am. Rob. | 17 | 100 | 31,400 | 53.38 | 2 | 0.04(0.08) |
| C.-b. C. | 17 | 30 | 2,826 | 4.80 | 4 | 0.83 |
| Pil. Wood. | 17 | 150 | 70,650 | 120.11 | 2 | 0.02 |
| Var. Th. | 17 | 100 | 31,400 | 53.38 | + | + |
| Ru. Hum. | 17 | 20 | 1,256 | 2.14 | + | + |
| St. Jay | 17 | 100 | 31,400 | 53.38 | 3 | 0.06 |
| Ha. Wood. | 17 | 110 | 37,994 | 64.59 | 2 | 0.03 |
| Song Sp. | 17 | 100 | 31,400 | 53.38 | 1 | 0.02(0.04) |
| Town. W. | 17 | 50 | 7,850 | 13.35 | 1 | 0.07(0.14) |

Summer Census--Marsh/Swamp (M/S)

| Species | Stations | Detection distance (r) | $\pi r^2$ | Hearing area(hectares) | Birds | Birds/ha |
|---|---|---|---|---|---|---|
| R.-w. B. | 9 | 130 | 53,066 | 47.76 | 14 | 0.29 |
| MacG. W. | 9 | 100 | 31,400 | 28.26 | 9 | 0.32(0.64) |
| Var. Th. | 9 | 170 | 90,746 | 81.67 | 1 | 0.01 |
| Swa. Th. | 9 | 200 | 125,600 | 113.04 | 8 | 0.07(0.14) |
| Wil. Fly. | 9 | 100 | 31,400 | 28.26 | 17 | 0.60 |
| Com. Yel. | 9 | 70 | 15,386 | 13.85 | 12 | 0.87(1.74) |
| Song Sp. | 9 | 100 | 31,400 | 28.26 | 9 | 0.32(0.64) |
| B.-c. C. | 9 | 50 | 7,850 | 7.07 | 2 | 0.28 |
| Ha. Wood. | 9 | 130 | 53,066 | 47.76 | 3 | 0.06 |
| C.-b. C. | 9 | 50 | 7,850 | 7.07 | + | + |
| Wils. W. | 9 | 170 | 90,746 | 81.67 | 1 | 0.01(0.02) |
| St. Jay | 9 | 200 | 125,600 | 113.04 | 4 | 0.04 |
| Town. W. | 9 | 90 | 25,434 | 22.90 | + | + |
| Win. Wr. | 9 | 90 | 25,434 | 22.90 | 1 | 0.04 |
| We. Fly. | 9 | 100 | 31,400 | 28.26 | 2 | 0.07 |

Summer Census--Marsh/Swamp (M/S) - continued.

| Species | Stations | Detection distance (r) | $\pi r^2$ | Hearing area(hectares) | Birds | Birds/ha |
|---|---|---|---|---|---|---|
| Am. Rob. | 9 | 200 | 125,600 | 113.04 | 2 | 0.02 |
| O.-c. W. | 9 | 150 | 70,650 | 63.59 | 5 | 0.08(0.16) |
| Com. Crow | 9 | 170 | 90,746 | 81.67 | 1 | 0.01 |

Fall Census--Early Successional Forest (FE)

| Species | Stations | Detection distance (r) | $\pi r^2$ | Hearing area(hectares) | Birds | Birds/ha |
|---|---|---|---|---|---|---|
| D.-e. Ju. | 10 | 70 | 15,386 | 15.39 | 23 | 1.49 |
| G.-c. K. | 10 | 50 | 7,850 | 7.85 | 1 | 0.13 |
| B.-c. C. | 10 | 50 | 7,850 | 7.85 | 8 | 1.02 |
| R.-s. Tow. | 10 | 100 | 31,400 | 31.40 | 2 | 0.06 |
| Song. Sp. | 10 | 100 | 31,400 | 31.40 | 9 | 0.29 |
| Am. Rob. | 10 | 200 | 125,600 | 125.60 | 5 | 0.04 |
| W.-c. Sp. | 10 | 150 | 70,650 | 70.65 | 10 | 0.14 |
| St. Jay | 10 | 200 | 125,600 | 125.60 | 5 | 0.04 |
| Y.-r. W. | 10 | 50 | 7,850 | 7.85 | 2 | 0.25 |
| Com. Crow | 10 | 170 | 90,746 | 90.75 | + | + |

Fall Census—Pole Stage Coniferous Forest (FCP)

| Species | Stations | Detection distance (r) | $\pi r^2$ | Hearing area(hectares) | Birds | Birds/ha |
|---|---|---|---|---|---|---|
| Win. Wr. | 28 | 50 | 7,850 | 21.98 | 17 | 0.77 |
| R.-s. Tow. | 28 | 60 | 11,304 | 31.65 | 3 | 0.09 |
| G.-c. K. | 28 | 30 | 2,826 | 7.91 | 61 | 7.70 |
| Var. Th. | 28 | 100 | 31,400 | 87.92 | 21 | 0.24 |
| Am. Rob. | 28 | 100 | 31,400 | 87.92 | 18 | 0.20 |
| B.-c. C. | 28 | 30 | 2,826 | 7.91 | 2 | 0.25 |
| D.-e. Ju. | 28 | 50 | 7,850 | 21.98 | 12 | 0.55 |
| C.-b. C. | 28 | 30 | 2,826 | 7.91 | 8 | 1.01 |
| Town. W. | 28 | 50 | 7,850 | 21.98 | 1 | 0.05 |
| Song Sp. | 28 | 100 | 31,400 | [illegible] | 5 | 0.06 |
| St. Jay | 28 | 100 | 31,400 | 87.92 | 4 | 0.05 |
| Com. Crow | 28 | 100 | 31,400 | 87.92 | 1 | 0.01 |
| Her. Th. | 28 | 60 | 11,304 | 31.65 | 6 | 0.19 |
| Pil. Wood. | 28 | 150 | 70,650 | 197.82 | 1 | 0.01 |
| Swa. Th. | 28 | 100 | 31,400 | 87.92 | 1 | 0.01 |
| Com. Flick. | 28 | 130 | 53,066 | 148.58 | 4 | 0.03 |

Fall Census--Mixed Forest (FM)

| Species | Stations | Detection distance (r) | $\pi r^2$ | Hearing area(hectares) | Birds | Birds/ha |
|---|---|---|---|---|---|---|
| Var. Th. | 28 | 100 | 31,400 | 87.92 | 17 | 0.19 |
| C.-b. C. | 28 | 30 | 2,826 | 7.91 | 20 | 2.53 |
| St. Jay | 28 | 100 | 31,400 | 87.92 | 9 | 0.10 |
| Song Sp. | 28 | 100 | 31,400 | 87.92 | 3 | 0.03 |
| Pil. Wood. | 28 | 150 | 70,650 | 197.82 | + | + |
| G.-c. K. | 28 | 30 | 2,826 | 7.91 | 19 | 2.40 |
| Com. Crow | 28 | 100 | 31,400 | 87.92 | 3 | 0.03 |
| Am. Rob. | 28 | 100 | 31,400 | 87.92 | 2 | 0.02 |
| Her. Th. | 28 | 60 | 11,304 | 31.65 | 1 | 0.03 |
| Win. Wr. | 28 | 50 | 7,850 | 21.98 | 4 | 0.18 |
| Ha. Wood. | 28 | 110 | 37,994 | 106.38 | 2 | 0.02 |
| D.-e. Ju. | 28 | 50 | 7,850 | 21.98 | 1 | 0.05 |

Fall Census—Old Growth Coniferous Forest (FCM/O)

| Species | Stations | Detection distance (r) | $\pi r^2$ | Hearing area(hectares) | Birds | Birds/ha |
|---|---|---|---|---|---|---|
| Ha. Wood. | 17 | 110 | 37,994 | 64.59 | 2 | 0.03 |
| Var. Th. | 17 | 100 | 31,400 | 53.38 | 6 | 0.11 |
| G.-c. K. | 17 | 30 | 2,826 | 4.80 | 20 | 4.17 |
| St. Jay | 17 | 100 | 31,400 | 53.38 | 8 | 0.15 |
| C.-b. C. | 17 | 30 | 2,826 | 4.80 | 14 | 2.92 |
| Win. Wr. | 17 | 50 | 7,850 | 13.35 | 15 | 1.12 |
| Am. Rob. | 17 | 100 | 31,400 | 53.38 | 5 | 0.09 |
| Song Sp. | 17 | 100 | 31,400 | 53.38 | 2 | 0.04 |
| D.-e. Ju. | 17 | 50 | 7,850 | 13.35 | 5 | 0.37 |
| Com. Flick. | 17 | 130 | 53,066 | 90.21 | 1 | 0.01 |

Fall Census--Marsh/Swamp(M/S)

| Species | Stations | Detection distance (r) | $\pi r^2$ | Hearing area(hectares) | Birds | Birds/ha |
|---|---|---|---|---|---|---|
| Com. Yel. | 9 | 70 | 15,386 | 13.85 | 16 | 1.16 |
| D.-e. Ju. | 9 | 70 | 15,386 | 13.85 | 4 | 0.29 |
| St. Jay | 9 | 200 | 125,600 | 113.04 | 10 | 0.09 |
| Song Sp. | 9 | 100 | 31,400 | 28.26 | 13 | 0.46 |
| G.-c. K. | 9 | 50 | 7,850 | 7.07 | 4 | 0.57 |
| Ha. Wood. | 9 | 130 | 53,066 | 47.76 | 1 | 0.02 |
| Com. Crow | 9 | 170 | 90,746 | 81.67 | + | + |
| Pil. Wood. | 9 | 200 | 125,600 | 113.04 | 1 | 0.01 |
| Var. Th. | 9 | 170 | 90,746 | 81.67 | 1 | 0.01 |
| R.-w. B. | 9 | 130 | 53,066 | 47.76 | 1 | 0.02 |
| Am. Rob. | 9 | 200 | 125,600 | 113.04 | 9 | 0.08 |
| R.-s. Tow. | 9 | 100 | 31,400 | 28.26 | 1 | 0.04 |
| C.-b. C. | 9 | 50 | 7,850 | 7.07 | + | + |
| O.-c. W. | 9 | 150 | 70,650 | 63.59 | 1 | 0.02 |
| Com. Flick. | 9 | 200 | 125,600 | 113.04 | + | + |

## Appendix G

Calculations for estimated breeding densities of common non-game birds in three habitat types, North Fork Snoqualmie basin, 24 June - 3 July 1980.

Early Successional Forest/Marsh (FE/M)

| Species | Stations | Detection distance (r) | $\pi r^2$ | Hearing area (hectares) | Birds | Birds/ha |
|---|---|---|---|---|---|---|
| Swa. Th. | 1 (9)* | 200 | 125,600 | 113.04 | 25 | 0.22 (0.44)** |
| D.-e. Ju. | 1 (9) | 70 | 15,386 | 13.85 | 9 | 0.65 (1.30) |
| Win. Wr. | 1 (9) | 90 | 25,434 | 22.89 | 1 | 0.04 (0.08) |
| Wil. Fly. | 1 (9) | 100 | 31,400 | 28.26 | 19 | 0.67 (1.34) |
| O.-c. W. | 1 (9) | 150 | 70,650 | 63.59 | 11 | 0.17 (0.34) |
| St. Jay | 1 (9) | 200 | 125,600 | 113.04 | 4 | 0.04 |
| Com. Flick. | 1 (9) | 200 | 125,600 | 113.04 | 2 | 0.02 |
| Wils. W. | 1 (9) | 170 | 90,746 | 81.67 | 1 | 0.01 (0.02) |
| R.-s. Tow. | 1 (9) | 100 | 31,400 | 28.26 | 5 | 0.18 |
| Y.-r. W. | 1 (9) | 50 | 7,850 | 7.07 | 2 | 0.28 (0.56) |
| Ru. Hum. | 1 (9) | 30 | 2,826 | 2.54 | 4 | 1.57 |
| MacG. W. | 1 (9) | 100 | 31,400 | 28.26 | 10 | 0.35 (0.70) |
| Com. Yel. | 1 (9) | 70 | 15,386 | 13.85 | 15 | 1.08 (2.16) |
| Am. Rob. | 1 (9) | 200 | 125,600 | 113.04 | 5 | 0.04 |
| Com. Crow | 1 (9) | 170 | 90,746 | 81.67 | +*** | + |
| War. Vir. | 1 (9) | 170 | 90,746 | 81.67 | 1 | 0.01 (0.02) |
| Song Sp. | 1 (9) | 100 | 31,400 | 28.26 | 4 | 0.14 (0.28) |
| Ha. Wood. | 1 (9) | 130 | 53,066 | 47.76 | 3 | 0.06 |
| B.-c. C. | 1 (9) | 50 | 7,850 | 7.07 | + | + |

*Because the habitat unit was small, nine listening stops were repeated at the same station.

**Numbers in parentheses are for both sexes, where only singing males were counted.

***A "+" means that bird was observed outside of detection distance.

Broadleaf Forest (FB)

| Species | Stations | Detection distance (r) | $\pi r^2$ | Hearing area (hectares) | Birds | Birds/ha |
|---|---|---|---|---|---|---|
| We. Fly. | 3 (15)* | 50 | 7,850 | 11.78 | 5 | 0.42 |
| Win. Wr. | 3 (15) | 50 | 7,850 | 11.78 | + | + |
| Swa. Th. | 3 (15) | 100 | 31,400 | 47.10 | 25 | 0.53 |
| Var. Th. | 3 (15) | 100 | 31,400 | 47.10 | 1 | 0.02 (0.04) |
| Song Sp. | 3 (15) | 100 | 31,400 | 47.10 | 5 | 0.11 (0.22) |
| Wils. W. | 3 (15) | 100 | 31,400 | 47.10 | 11 | 0.23 (0.46) |
| War. Vir. | 3 (15) | 100 | 31,400 | 47.10 | 20 | 0.42 (0.84) |
| D.-e. Ju. | 3 (15) | 50 | 7,850 | 11.78 | 2 | 0.17 |
| Hut. Vir. | 3 (15) | 50 | 7,850 | 11.78 | 2 | 0.17 (0.34) |
| MacG. W. | 3 (15) | 70 | 15,386 | 23.08 | 4 | 0.17 (0.34) |
| B.-c. C. | 3 (15) | 30 | 2,826 | 4.24 | 2 | 0.47 |
| O.-c. W. | 3 (15) | 60 | 11,304 | 16.96 | 1 | 0.06 (0.12) |

*Because the habitat unit was small, five listening stops were repeated at each of three stations.

Bog (B)

| Species | Stations | Detection distance (r) | $\pi r^2$ | Hearing area (hectares) | Birds | Birds/ha |
|---|---|---|---|---|---|---|
| Pil. Wood. | 2 (12)* | 200 | 125,600 | 150.72 | 8 | 0.05 |
| Song Sp. | 2 (12) | 100 | 31,400 | 37.68 | 15 | 0.40 (0.80) |
| Com. Flick. | 2 (12) | 200 | 125,600 | 150.72 | 6 | 0.04 |
| Com. Yel. | 2 (12) | 70 | 15,386 | 18.46 | 17 | 0.92 (1.84) |
| St. Jay | 2 (12) | 200 | 125,600 | 150.72 | 21 | 0.14 |
| Swa. Th. | 2 (12) | 200 | 125,600 | 150.72 | 11 | 0.07 |
| Win. Wr. | 2 (12) | 90 | 25,434 | 30.52 | 3 | 0.10 (0.20) |
| We. Fly. | 2 (12) | 100 | 31,400 | 37.68 | 17 | 0.45 |
| Ha. Wood. | 2 (12) | 130 | 53,066 | 63.68 | 9 | 0.14 |
| Am. Rob. | 2 (12) | 200 | 125,600 | 150.72 | 5 | 0.03 (0.06) |
| Com. Crow | 2 (12) | 170 | 90,746 | 108.90 | 3 | 0.03 |
| MacG. W. | 2 (12) | 100 | 31,400 | 37.68 | 1 | 0.03 (0.06) |
| Wils. W. | 2 (12) | 170 | 90,746 | 108.90 | 2 | 0.02 (0.04) |
| Wil. Fly. | 2 (12) | 100 | 31,400 | 37.68 | + | + |
| O.-c. W. | 2 (12) | 150 | 70,650 | 84.78 | 1 | 0.01 (0.02) |
| D.-e. Ju. | 2 (12) | 70 | 15,386 | 18.46 | + | + |

*Because the habitat unit was small, six listening stops were repeated at each of two stations.

Appendix H

Calculations for estimated number of deer hunter use-days in North Fork Snoqualmie basin, 1979.

## Weekday Deer Hunter Use in Snoqualmie Game Management Unit

As in other years, the 1979 deer hunting season was split into two parts (seasons). The early season was 13 October - 8 November. The late season was 24 - 28 November. The late season occurred during the rut, when male deer are much less wary than at other times. Deer hunter use and harvest differ considerably for the two seasons. Therefore, in estimating total weekday hunter use, we calculated separate values for the two seasons, and added the results. This procedure was unnecessary for weekend hunter use, because we assumed we counted all hunters.

The early season included 19 weekdays in 4 weeks of deer hunting. We ran our checking station one day in each of the four weeks. However, due to vehicle troubles, our first day's sample was incomplete and we discarded it. For the remaining 3 sample days, we counted 141 hunters.

During the late season, there were 3 weekdays of deer hunting. On our single sample day, we counted 126 hunters. We used the following formula to estimate weekday hunter use-days ($H$) in the entire Snoqualmie Game Management Unit.

$$H = \frac{w}{s} \times n$$

where $w$, total number of weekdays in season = 19 (early season)
= 3 (late season)
$s$, total number of weekdays sampled = 3 (early season)
= 1 (late season)
$n$, total number of hunters counted = 141 (early season)
= 126 (late season)

The resulting estimates were 893 hunters during the early season and 378 hunters during the late season. Thus, total estimated weekday hunter use in the entire Snoqualmie Game Management Unit was 1,271 hunter use-days.

## Total Deer Hunter Use in North Fork Snoqualmie Basin

Total number of hunter use-days in the basin was estimated by multiplying the total number of hunters in the game management unit by the percent using the basin, and adding the results for weekdays and weekends (see next page).

| | Weekends | Weekdays | Total |
|---|---|---|---|
| Total hunters in entire Snoqualmie G.M.U. | 5,856 | 1,271 | 7,127 |
| Percent of hunters using basin | 30.0 | 38.2 | 31.5 |
| Estimated number of hunters using basin | 1,758 | 485 | 2,243 |

## Appendix I

Calculations for estimated deer harvest in North Fork Snoqualmie basin, 1979.

Assumptions were the same as for estimating weekday deer hunter use (see Appendix H). Therefore, we made separate estimates for early (13 October - 8 November) and late (24-28 November) seasons. We used the following formula to estimate weekday deer harvest ($H$) in the entire Snoqualmie Game Management Unit.

$$H = \frac{w}{s} \times n$$

where $w$, total number of weekdays in season = 19 (early season)
= 3 (late season)
$s$, total number of weekdays sampled = 3 (early season)
= 1 (late season)
$n$, total number of deer counted = 3 (early season)
= 5 (late season)

The resulting estimates are 19 deer harvested during the early season and 15 deer harvested during the late season. Thus, total estimated weekday deer harvest in the entire Snoqualmie Game Management Unit was 34 deer.

Assuming that the proportion of deer harvested in the basin is the same on weekdays as on weekends (27 percent), an estimated 9 deer (0.27 x 34) were harvested on weekdays in the basin. Adding this figure to the known weekend harvest total of 46 deer, gives an estimated yearly total of 55 deer harvested in the North Fork Snoqualmie basin during 1979.

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